3 vols

A
MANUAL OF CHEMISTRY;

CONTAINING

THE PRINCIPAL FACTS OF THE SCIENCE, ARRANGED IN THE
ORDER IN WHICH THEY ARE DISCUSSED AND ILLUSTRATED
IN THE LECTURES AT THE ROYAL INSTITUTION
OF GREAT BRITAIN.

BY

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Society of Petersburgh.

SECOND EDITION, IN THREE VOLUMES.

VOL. II.

LONDON:
JOHN MURRAY, ALBEMARLE-STREET.
1821.

LONDON
PRINTED BY WILLIAM CLOWES,
Northumberland-court.

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ERRATA.

Page 41, in the diagram, *for* = 30.5 *read* = 50.5.
— 47, line 17, for *toxide* read *protoxide.*
— 190, — 5 from bottom, *for* 147.5 *read* 135.
— 191, — 1, *for* SALTS OF COPPER *read* SALTS OF COBALT.
— 201, — 11 from bottom, *for* Sulphur *read* Pyrites.

In Section XI. the number 55 is occasionally assumed as the equivalent of tin, instead of 55.5.

Page 249. In Paragraph 1146, *for* 120 lbs. of common salt *read* 40 lbs.

— 251. In Paragraph 1151, insert " hence its use in washing calomel," after the word " water;" and erase the same words at the end of the paragraph.

— 272. In Paragraph 1219, after the words *slip of silver,* erase the remaining lines and substitute the following :

to each of the wires communicating with the poles of a Voltaic battery, and immersing them in muriatic acid : the silver attached to the positive pole instantly acquires a coating of chloride of silver.

Page 294. In Paragraph 1297, the mode of forming sulphate of platinum should have been stated ; it consists in acidifying sulphuret of platinum by nitric acid.

At Page 74. an error occurs in the numeration of the paragraphs, (618 following 647,) which if not observed, may lead to inconsistency in the references.

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CHAPTER V.

OF THE METALS, AND THEIR COMBINATIONS.

501. THE metals constitute a numerous and important class of simple substances; many of them were diligently examined by the older chemists, who have left us valuable information concerning them; many are of more recent discovery; and the existence of several others has been demonstrated within the last twenty years.

The metals are forty-two in number.

1 Gold
2 Silver
3 Copper
4 Iron
5 Mercury
6 Tin
7 Lead
8 Zinc
9 Bismuth
10 Antimony

11 Arsenic
12 Cobalt
13 Platinum
14 Nickel
15 Manganese
16 Tungsten
17 Tellurium
18 Molybdenum
19 Uranium
20 Titanium
21 Chromium
22 Columbium
23 Palladium
24 Rhodium
25 Iridium
26 Osmium
27 Cerium
28 Potassium
29 Sodium
30 Lithium
31 Barium
32 Calcium
33 Strontium
34 Magnesium
35 Silicium
36 Alumium
37 Yttrium
38 Glucium
39 Zirconium
40 Thorinum
41 Selenium
42 Cadmium

502. Of these metals the first seven were known in very remote ages. The ancients designated them by the names of the planets, to which they were supposed to have some mysterious relation; and each was denoted by a particular symbol, representing both the metal and the planet.

Gold was the	Sun, and was thus represented	☉
Silver	Moon	☽
Mercury	Mercury	☿
Copper	Venus	♀
Iron	Mars	♂
Tin	Jupiter	♃
Lead	Saturn	♄

Zinc was not known to the ancients, though they were probably acquainted with its ores, and with their property of forming brass when fused with copper. (PLINY, Lib. xxxiv. cap. 2 and 10.) The word *Zinc* first occurs in the writings of Paracelsus, who died in 1541. Bismuth is mentioned in the *Bermannus* of Agricola, written about 1530. Antimony was first obtained in its pure state by Basil Valentine towards the end of the 15th century. The process is described in his *Currus Triumphalis Antimonii.* Arsenic and Cobalt were discovered by Brandt in 1733, *(Acta Upsal.* 1733 and 1742); their ores were known at a much earlier period. Platinum was first recognised as a peculiar body in 1741, by Mr. Charles Wood, Assay-Master in Jamaica. *(Phil. Trans.* Vol. xliv.) In 1751, the distinctive characters of Nickel were shown by Cronstedt *(Stockholm Transactions)*, and Manganese was obtained by Gahn in 1774. (BERGMAN'S *Opuscula*, Vol. ii.) Tungsten was discovered by M. M. Delhuyart in 1781. *(Mémoires de Toulouse)*. Tellurium and Molybdenum by Muller and Hielm, in 1782. Uranium by Klaproth in 1789. Titanium by Mr. Gregor, in 1789. Chromium by Vauquelin, in 1797. *(Annales de Chimie*, Vol. xxv.) In 1802, Mr. Hatchett discovered Columbium. *(Phil. Trans.)* Palladium and Rhodium were discovered by Dr. Wollaston; and Iridium and Osmium by Mr. Tennant, all in 1803. *(Phil. Trans.)* Cerium was announced in 1804 by M. M. Hisinger and Berzelius. (GEHLEN'S *Journal*, ii.) Potassium and Sodium were discovered in 1807 by Sir H. Davy, whose experiments also led to the discovery of the metallic nature of the ten following bodies. Thorinum and Selenium were announced by Berzelius in 1815 and in 1817; and Mr. Stromeyer, of Gottingen, discovered Cadmium in 1818.

503. The circumstances under which metals are found in the earth, will be stated in the chapter of this work relating to geology. It may here be remarked, that they seldom occur in an uncombined state, but almost always united to other substances, as in the four following classes:—

i. *Native metals* are those which occur pure or alloyed, and have but a feeble attraction for oxygen; such as platinum, gold, silver, mercury, and copper.

ii. *Metals combined with simple supporters of combustion.* The compounds belonging to this class are chiefly *native metallic oxides*: there are also a few native *chlorides*, but no iodides have hitherto been discovered. The *fluorides*, of which there are a few, may also be regarded as belonging to this class.

iii. *Metals combined with simple inflammables.* This class includes the *native metallic sulphurets,* a very numerous and important series of ores. One *native carburet* only is known, that of iron. There are no native hydrurets, phosphurets, nor borurets.

iv. *Metals in combination with acids—Metallic salts.* Of these the most common are the native *carbonates, sulphates,* and *phosphates:* there are a few native *borates;* and a few species belong also to this class in which the oxide is united to a *metallic acid:* such as the *native arseniates, chromates, tungstates,* and *molybdates.*

504. The metals, as a class, are characterized by a peculiar lustre and perfect opacity: they are excellent conductors of heat, (74) and of electricity (102).

505. There is the greatest difference in the specific gravity of the different metals, the heaviest and lightest solids being included in the list.

The principal metals, arranged according to their specific gravities, stand as follow:

1	Platinum	21.00
2	Gold	19.30
3	Tungsten	17.50
4	Mercury	13.50
5	Palladium	11.50
6	Lead	11.35
7	Silver	10.50
8	Bismuth	9.80
9	Uranium	9.00
10	Copper	8.90
11	Arsenic	8.35

12	Nickel	8.25
13	Cobalt	8.00
14	Iron	7.78
15	Molybdenum	7.40
16	Tin	7.30
17	Zinc	7.00
18	Manganese	6.85
19	Antimony	6.70
20	Tellurium	6.10
21	Sodium	0.972
22	Potassium	0.865

506. The specific gravity of solids and liquids is always expressed in numbers referring to water as = 1.

To ascertain the specific gravity of solids we employ a delicate balance, so contrived as to admit of substances being attached to one of the scales by means of a horse-hair or a fine thread of silk. The absolute weight of the body thus suspended is then very carefully ascertained: it is next immersed in distilled water, of the temperature of 60°; and the beam being again brought to an equilibrium, we learn the weight lost by its immersion; or, in other words, we ascertain the weight of its bulk of pure water. We now divide the sum of its absolute weight by that of the weight which it ost in water, and the quotient is its *specific weight*, or gravity, compared with water of the temperature of 60°.

Suppose a substance, weighing 360 grains, to lose 60 by immersion in water, the specific gravity of that substance will be = 6; for $360 \div 60 = 6$.

507. For ascertaining the specific gravity of liquids,

we generally employ a thin phial, holding 1000 grains of distilled water, at the temperature of 60°. If filled with any other liquid, and weighed, we learn its specific gravity ; thus we should find that it would contain 13500 grains of mercury ; 1850 grains of sulphuric acid ; 1420 grains of nitric acid, *&c.*, which numbers of course represent the specific gravities of those liquids.

A bottle, however, holding 1000 grains is often inconveniently large, and a small and thin globular phial, with a piece of thermometer tube ground into it by way of stopper, will be found more useful : such a phial should not weigh more than from 50 to 60 grains, and may contain between 4 and 500 grains of water. To use it, it should be accurately counterbalanced in a delicate pair of scales, and then filled with distilled water, and the stopper thrust in, the capillary opening in which allows a little to ooze out, and prevents the likelihood of bursting the phial ; it is then to be wiped clean and dry, and again carefully weighed, by which the quantity of water it contains is ascertained ; the water being poured out, it is next filled with the liquid whose specific gravity is required, taking care that it is of the same temperature as the water ; we then weigh as before, and divide the weight by the former weight of water, the product gives the specific gravity required. Thus, suppose the phial to contain 425 grains of water at the temperature of 45°, it will be found to hold 5737.5 grains of pure mercury of the same temperature ; and $5737.5 \div 425 = 13.5$ the sp. gr. of mercury. Or, supposing the liquid lighter than water, such as alcohol, of which we may assume the phial to contain 350.5; then 350.5 ÷ 425 = 0.824 the sp. gr. of the alcohol under trial.

508. Among the metals, some are *malleable*, others *brittle*.

Malleability, or the capacity of being extended by the hammer, belongs to the following metals, in the order following:

Gold
Silver
Copper
Tin
Cadmium
Platinum
Lead
Zinc
Iron
Nickel
Palladium

Potassium, sodium, and frozen mercury, are also malleable.

509. The malleable metals are also *ductile*; that is, they admit of being drawn out into wires. They are arranged according to ductility as follows:

Gold
Silver
Platinum
Iron
Copper
Zinc

Tin
Lead
Nickel
Palladium.

510. Different metallic wires are possessed of different degrees of *tenacity*, by which is meant the power of supporting a weight without breaking. According to the experiments of Guyton Morveau, the following are the weights capable of being sustained by wires $\frac{787}{1000}$ths of a line in diameter.—*Annales de Chimie*, lxxi.:

	lbs. avoird. decimal parts.
A wire of Iron supports....	549.250
Copper	302.278
Platinum	274.320
Silver..........	187.137
Gold	150.753
Zinc	109.540
Tin.............	34.630
Lead	27.621

511. The following metals are brittle:

Antimony
Arsenic
Bismuth
Cerium
Chrome
Cobalt
Columbium
Manganese
Molybdenum

Tellurium
Tungsten
Titanium
Uranium.

512. None of the metals are very *hard*, and many so soft as to yield to the nail. In the following table some of the metals are arranged in the order of their hardness:

Tungsten
Palladium
Manganese
Iron
Nickel
Platinum
Copper
Silver
Bismuth
Gold
Zinc
Antimony
Cobalt
Tin
Arsenic
Lead.

Elasticity and sonorousness belong to the hardest metals only.

Such are the essential physical characters of the metals; they also resemble each other in many of their chemical properties, as the following general observations show:

513. *Action of Heat.*—The metals are all susceptible of fusion by heat, but the temperatures at which they liquefy are extremely various. Mercury is fluid at all common temperatures, and requires to be cooled to — 39° before it congeals. Potassium melts at 150°, and sodium at 200°: arsenic at 360°; tin at 450°; lead at 600°; zinc at 700°; and antimony at 800°. Silver, gold, and copper require a bright cherry-red heat; iron, nickel, and cobalt, a white heat; manganese and palladium, an intense white heat; molybdenum, uranium, tungsten, and chrome, are only very imperfectly agglutinated at the highest temperatures of our furnaces; and titanium, cerium, osmium, iridium, rhodium, platinum, and columbium, require the intense heat produced by an inflamed current of oxygen and hydrogen, or that of Voltaic electricity.

At higher temperatures than that required for their fusion many of the metals are volatile, and may be distilled in close vessels. Mercury, arsenic, potassium, tellurium, and zinc, are volatile at a dull red heat. Gold and silver are converted into vapour when exposed to the intense heat of the focus of a burning lens; and several of the other metals boil and evaporate under similar circumstances. It is probable that this would happen to all of them, if raised to sufficiently high temperatures.

514. *Action of Oxygen.*—When the metals are exposed at ordinary temperatures to the action of oxygen, or of common air, which produces analogous, though less powerful effects, they are very differently affected. If the gas be perfectly dry, very few of them suffer any change, unless heated in it; they then lose their

metallic characters, and form a very important series of compounds, the *metallic oxides*.

A few of the metals resist the action of heat and air so completely, that they may be kept in fusion in an open crucible for many hours without undergoing change. This is the case with gold and silver, and a few others; hence they were called *perfect* or *noble* metals: they may, however, be oxidized by the Voltaic flame; or by passing a strong electric discharge through them, when drawn into very fine wire.

Other metals readily absorb oxygen when exposed to a temperature approaching a red heat; as iron, mercury, nickel, *&c.*; others absorb it when in fusion, as lead, tin, antimony, *&c.*; others at lower, or even at common temperatures, as arsenic, manganese, sodium, potassium, *&c.*

That the metals have very different attractive powers in regard to oxygen is also shown by the circumstance of one metal being frequently oxidized at the expense of another; thus the oxide of mercury, heated with metallic iron, produces metallic mercury and oxide of iron; potassium, heated with oxide of manganese, becomes oxidized, and metallic manganese is obtained.

Some of the oxides are decomposed by mere exposure to heat, as those of gold, mercury, *&c.*; others require the joint action of heat, and some body having a high attraction for oxygen, such as charcoal. Thus when oxide of lead is heated with charcoal, carbonic acid gas is evolved, and metallic lead obtained.

Each metal has a certain definite quantity of oxygen with which it combines; and where the same metal unites in more than one proportion with oxygen, in the second, third, and other compounds, it is a multiple of that in the first, consistent with the law of definite proportions (46). Thus 100 parts of mercury combine with 4 of oxygen to produce the *protoxide*, and with 8 to produce the *peroxide*. Copper also forms two oxides; in the one 12.5 of oxygen are united to 100 of metal, and in the other 25.

Among the combinations of metals with oxygen, some are insoluble in water, or nearly so, and have neither taste nor smell; others are soluble and sour, constituting the *metallic acids;* others are soluble and alcaline, forming the *fixed alcalis* and *alcaline earths.* They are of all colours, and frequently the same metal united to different proportions of oxygen produces compounds differing in colour: thus we have the *black* and *red* oxide of mercury, the *white* and the *black* oxide of manganese, *&c.*

515. *Action of Chlorine.*—All the metals appear susceptible of combining with chlorine, and of producing a class of compounds which may be termed *metallic chlorides.*

There are a few of the metals which resist the action of chlorine at common temperatures, but when heated they all combine with it; some slowly, others rapidly and with intense ignition. Copper leaf, powdered antimony, arsenic, *&c.*, burn when thrown into the gas: mercury and iron inflame when gently heated in it; silver, gold, and platinum quietly absorb it.

The attraction of chlorine for metals is greater than that of oxygen; consequently, when a metallic oxide is heated in chlorine, oxygen is evolved, and a chloride formed. The insoluble chlorides are also formed by adding solution of chlorine, or of the soluble chlorides, or of muriatic acid, to the soluble metallic salts. Thus chloride of silver, which is insoluble, is thrown down from the soluble nitrate of silver by solution of chlorine, of muriatic acid, and of common salt.

The physical and chemical properties of the chlorides are extremely various. They are nearly of all colours. Some are unchanged by heat; others undergo decomposition. Some are soluble, others insoluble, in water. Several of them decompose water, giving rise to the formation of muriatic acid, and an oxide; or in some cases to a muriate. The same metal often forms more than one compound with chlorine, and these compounds are designated as the oxides. Thus we have the *protochloride* and *perchloride* of mercury, *&c.*

Many of the metals decompose muriatic acid, in which case hydrogen is evolved, and a metallic chloride produced; and when metallic oxides are heated in muriatic acid, they generally give rise to the formation of a chloride and water.

516. *Action of Chloric Acid.*—The compounds of the metallic oxides with chloric acid are decomposed by heat with the copious evolution of oxygen, and a chloride generally remains: some of these salts have been long known, others only recently investigated. The *oxychlorates* have been scarcely examined.

517. *Action of Iodine.*—Iodine aided by heat acts upon many of the metals, and produces *metallic iodides.* Some of these are soluble in water without decomposition; others decompose water and produce *hydriodates;* others are insoluble. The insoluble iodides may gene-

rally be formed by adding a solution of iodine or of hydriodic acid to the soluble metallic salts.

Iodine often combines in more than one proportion with metals, forming a *protiodide* and a *periodide.*

518. *Action of Iodic Acid.*—The compounds of this acid with the metallic oxides have been but little examined: they are decomposed by heat, sometimes with the evolution of oxygen only; at others, iodine is also given off.

519. *Action of Hydrogen.*—Hydrogen forms permanent compounds with two of the metals only, namely, arsenic and tellurium. It appears to combine with each in two proportions, forming two solid compounds, the *hydrurets* or *hydrogurets* of arsenic and tellurium; and two gaseous compounds, *arsenuretted* and *telluretted hydrogen.* At high temperatures it dissolves potassium, forming *potassiuretted hydrogen gas.*

There are many of the metallic oxides, and a few of the chlorides, which are decomposed by hydrogen: the oxides are reduced with the formation of water, and the chlorides with the production of muriatic acid.

520. *Action of Water.*—Those metals which are speedily acted upon by common air and oxygen, are also generally susceptible of decomposing water; some of them rapidly, others slowly. There are some metals which are not acted upon by air deprived of moisture, nor by water deprived of air; but moist air, or water containing air, effect their oxidizement: this appears to be the case with iron.—Dr. MARSHALL HALL. *Quarterly Journal,* vii. 55.

Water combines with some of the metallic oxides, and produces *hydrated oxides,* or *metallic hydrates.* In these the relative proportion of water is definite. Some are easily decomposed by heat, as hydrate of copper; others retain water even when heated to redness, as hydrate of potassa.

521. *Action of Nitric Acid.*—As no metal is soluble in an acid except in the state of oxide, and as the greater number of metals are capable of decomposing nitric acid, and of resolving it into some of the other nitric compounds, nitric acid is a very generally acting solvent of these bodies. It dissolves all the metallic oxides and produces a numerous class of *nitrates*, which if prepared with heat and with excess of acid, generally contain the metal at its maximum of oxidizement. The nitrates are all decomposed by a red heat; they give off oxygen and nitrogen, either separate, or combined, and the metallic oxide remains. They are also decomposed when heated with sulphur, phosphorus, or charcoal; and sulphurous, phosphoric, and carbonic acids are formed; the phosphoric, being a fixed acid, remains united to the metallic oxide; while the sulphurous and carbonic acids are usually expelled. The nitrates are decomposed by sulphuric acid, nitric acid is evolved, and *sulphates* are formed.

In the neutral nitrates the proportion of oxygen in the acid is to that in the base as 5 to 1. Thus in the nitrate of potassa 45 parts of potassa, containing 7.5 of oxygen, are combined with 50.5 of nitric acid, containing 37.5 of oxygen; and in the pernitrate of copper, 75 parts of peroxide of copper containing 15 of oxygen, are combined with 101 of nitric acid, containing 75 of oxygen.

522. *Action of Ammonia.*—At high temperatures

some of the metals are capable of decomposing ammonia. Liquid ammonia dissolves several of the metallic oxides, and with some of them forms crystallizable compounds. The compounds of ammonia with the oxides of gold, silver, and platinum, detonate when heated, and the oxide and the ammonia are both decomposed.

523. *Action of Sulphur.*—All the metals appear capable of forming *sulphurets.* These are in some cases formed by heating the metal with sulphur; in others, by decomposing the sulphates; and in others, by the action of sulphuretted hydrogen. The sulphurets are in general brittle; some have a metallic lustre; others are without lustre. Some are soluble, others insoluble in water. Where the same metal forms two sulphurets, the sulphur in those containing the largest proportion is an exact simple multiple of the sulphur in those containing the smallest proportion. When the metallic sulphurets are heated some undergo no change, as those of sodium and potassium; others sublime unaltered as sulphuret of mercury; others lose a portion of their sulphur, and, if air be admitted, sulphurous acid escapes and the metal passes into the state of oxide, as sulphuret of lead; others again are entirely decomposed, the metal being completely reduced; this happens on heating sulphuret of platinum or of gold. It is doubtful whether any definite compounds of sulphur with the metallic oxides exist.

524. *Hyposulphurous acid* combines with the metallic oxides and produces a class of salts termed *hyposulphites.* Several of these have been examined by Mr. Herschel (*Edinburgh Philosophical Journal,* i.) In some of their characters they resemble the sulphites: they

are easily soluble; of a bitter or sweet taste; and decomposed by a heat below redness, and by almost all other acids. Their solutions readily dissolve chloride of silver.

525. *Sulphurous acid* combines with many of the metallic oxides, producing *sulphites;* in some instances oxygen is transferred from the oxide to the acid, and sulphates result.

The *sulphites* are soluble in water, and have a sulphurous taste and smell. Exposed to moist air, they absorb oxygen, and pass into the state of sulphates. They are decomposed by sulphuric acid, which expels sulphurous acid, and the salts are converted into sulphates. When perfectly pure they are not affected by solution of baryta.

526. *Hyposulphuric acid* forms with the metallic oxides a class of hyposulphates which have been very imperfectly examined. They do not afford precipitates with solution of baryta.

527. *Sulphuric acid,* in its concentrated state, is acted upon by a few of the metals only; when diluted, some of them are oxidized at the expense of the water, hydrogen is evolved, and the metallic oxide combines with the acid, producing a *sulphate.* In these cases the hydrogen evolved is the indicator of the quantity of oxygen transferred to the metal; every volume of hydrogen is the equivalent of half a volume of oxygen, and accordingly the production of 100 cubic inches of hydrogen, indicates the transfer of 50 of oxygen, or by weight of about 17 grains. As different metals unite to different weights of oxygen, they will obviously evolve different quantities of hydrogen. Thus, if one metal, to become soluble in sul-

phuric acid, require to be united with 15, and another with 30 per cent. of oxygen, the latter will evolve twice the volume of hydrogen, compared with the former.

As the evolution of hydrogen, during the solution of a metal in dilute sulphuric acid, is referable to its oxidizement, no hydrogen will be evolved by the action of the acid upon an oxide, but it will be merely dissolved.

The sulphates are an important class of salts. The greater number of them are soluble in water, and the solutions are rendered turbid by solutions of baryta. They are all decomposed at a red heat by charcoal, and most of them are thus converted into sulphurets; carbonic acid, and carbonic oxide, being at the same time evolved.

In the neutral sulphates the proportion of oxygen in the acid is to that in the base as 3 to 1. Thus sulphate of soda is composed of 29.5 soda containing 7.5 of oxygen, combined with 37.5 of sulphuric acid containing 22.5 of oxygen.

528. *Action of Sulphuretted Hydrogen.*—It seems doubtful whether any of the metals combine with sulphuretted hydrogen. It unites with several of their oxides, and forms *hydrosulphuretted oxides.* Many of these compounds are insoluble, and may be formed by adding a solution of sulphuretted hydrogen, or of hydrosulphuret of ammonia, to solutions of the respective metallic salts. Sometimes, however, a decomposition is effected in these cases, both of the sulphuretted hydrogen and of the oxide, and a metallic sulphuret is formed, the hydrogen combining with the oxygen of the oxide to form water, and the sulphur uniting to the metal. In a few cases the metallic oxide is reduced. The following table shows the effect of

sulphuretted hydrogen and of hydrosulphuret of ammonia upon solutions of several of the metals, as far as colour of the precipitate is concerned.

METAL.	SOLUTION.	SULPHURETTED HYDROGEN.	HYDROSULPHURET OF AMMONIA.
MANGANESE	Neutral protomuriate	No precipitate	Copious ochre yellow
IRON	Neutral protosulphate	Blackish and small in quantity	Black and abundant
Ditto	Permuriate	Abundant black	Black
ZINC	Muriate	A little opalescent and then milky	Straw colour and copious
TIN	Acid protomuriate	Brown	Deep orange
Ditto	Acid permuriate	At first 0, then yellow and copious	Apple green
CADMIUM . .	Muriate	Yellow	Yellow
COPPER . . .	Protomuriate	Deep brown	Brown
Ditto	Pernitrate	Black	Brown and black
LEAD	Muriate and nitrate	Black	Brown and black
ANTIMONY . .	Tartrate of antimony and potassa	Deep orange-red	Bright orange
BISMUTH . . .	Tartrate of bismuth and potassa	Deep brown	Deep brown
COBALT	Muriate	0 but blackish	Copious black
URANIUM . . .	Sulphate	Brown	Blackish brown
TITANIUM . . .	Acid muriate	0	Black
Ditto	Neutral sulphate	0	Green
CERIUM . . .			
TELLURIUM .			
ARSENIC . .	White oxide		
Ditto	Arsenic acid		
NICKEL	Sulphate	Brown	Black
MERCURY . .	Acid nitrate	Black, then gray, and black by excess of test	Black by excess of test
Ditto	Acid pernitrate	Ditto	Ditto
Ditto	Corrosive sublimate	Brown by excess of test	Ditto
RHODIUM . .			
PALLADIUM .			
SILVER	Nitrate	Black, and films of reduced silver	Brown
GOLD	Muriate	Black, and reduced gold	Yellow
PLATINUM . .	Nitrate	Deep brown	Pale brown

529. *Action of Phosphorus.*—Phosphorus combines with the greater number of the metals, forming a series of *metallic phosphurets.* There are two methods of forming them; either by heating a mixture of phosphorus and the metal, or projecting phosphorus upon the metal previously heated to redness; or by heating a mixture of the metal or its oxide, with phosphoric acid and charcoal. These phosphurets have a metallic lustre; if they contain a difficultly fusible metal, they are more fusible than the metal they contain; if an easily fusible metal, less so. They are mostly crystallizable, and totally or partially decomposable at a high temperature. The greater number of the phosphurets have only been examined by Pelletier,—*Annales de Chimie*, Tom. i. *et* xiii. and *Mémoires et Observations de Chimie.*

530. The *metallic phosphates* may be formed either by dissolving the oxides in phosphoric acid, or by adding a solution of phosphoric acid, or of an alcaline phosphate, to solutions of those metals which form insoluble or difficultly soluble phosphates. The greater number of the phosphates are decomposed by ignition with charcoal; and those containing volatile oxides are volatilized at high temperatures.

In the neutral phosphates the quantity of oxygen in the acid is to that in the base as 2 to 1. Thus phosphate of soda consists of 29.5 soda containing 7.5 oxygen, and 26 phosphoric acid containing 15 of oxygen.

531. When phosphorus is introduced into the solutions of those metals which have but a feeble attraction for oxygen, it reduces them to the metallic state. Thus gold, silver, and platinum are thrown down by im-

mersing a stick of phosphorus into their respective solutions.

532. *Action of Carbon.*—Carbon unites to very few of the metals, and of the metallic carburets, one only is of importance, namely, carburet of iron, or *steel.*

533. *Carbonic acid* unites with the greater number of the metallic oxides and forms *Carbonates,* of which the distinctive characters have already been noticed; many of them are of difficult solubility, and may be formed by adding an alcaline carbonate to the metallic solution. Of the carbonates some are entirely, and others only partially, decomposed at a red heat. Carbonate of magnesia, for instance, loses the whole of its carbonic acid at a red heat; carbonate of potassa retains it; and bi-carbonate of potassa loses one-half and passes into the state of carbonate.

534. *The action of Boron* upon the metals has not been investigated, though it appears from the experiments of Descotils, (*Recherches Physico-chymiques de* M. M. GAY-LUSSAC et THENARD) to be capable of uniting to platinum and iron. These compounds may be called *borurets.* The metallic *borates* are numerous, but mostly unimportant. Many of them are insoluble and easily formed by adding solution of boracic acid, or a soluble borate to the metallic solution.

535. *Action of the Metals upon each other.*—The metals may for the most part be combined with each other, forming a very important class of compounds, the *metallic alloys.* Various processes are adopted in the formation of alloys depending upon the nature of the metals. Many are prepared by simply fusing the

two metals in a covered crucible; but if there be a considerable difference in the specific gravity of the metals, the heavier will often subside, and the lower part of the bar or ingot, will differ in composition from the upper; this may be prevented by agitating the alloy till it solidifies. Mr. Hatchett found that when an alloy of gold and copper was cast into bars, the moulds being placed perpendicularly, the upper part of the bar contained more copper than the lower.—*Phil. Trans.* 1803.

Where one of the metals is very volatile, it should generally be added to the other after its fusion; and if both metals be volatile, they may be sometimes united by distilling them together.

It has been a question whether alloys are to be considered as compounds, or as mere mixtures; but their properties leave little doubt of their being real compounds, and in some cases they are found to unite in definite proportions only; and it is probable that all the alloys contain a definite compound of the two metals.

536. The principal characters of the alloys are the following:

i. We observe a change in the ductility, malleability, hardness, and colour. Malleability and ductility are usually impaired, and often in a remarkable degree: thus gold and lead, and gold and tin, form a brittle alloy. The alloy of copper and gold is harder than either of its component parts; and a minute quantity of arsenic added to copper, renders it white.

ii. The specific gravity of an alloy is rarely the mean of its component parts, in some cases an increase, in others a diminution of density having taken place, as shown by the following Table from Thenard.—*Traité de Chimie*, Vol. i. p. 394.

Alloys possessed of greater specific gravity than the mean of their components.	Alloys having a specific gravity inferior to the mean of their components.
Gold and Zinc	Gold and Silver
Tin	Iron
Bismuth	Lead
Antimony	Copper
Cobalt	Iridium
Silver and Zinc	Nickel
Lead	Silver and Copper
Tin	Copper and Lead
Bismuth	Iron and Bismuth
Antimony	Antimony
Copper and Zinc	Lead
Tin	Tin and Lead
Palladium	Palladium
Bismuth	Antimony
Antimony	Nickel and Arsenic
Lead and Bismuth	Zinc and Antimony
Antimony	
Platinum & Molybdenum	
Palladium and Bismuth	

iii. The fusibility of an alloy is generally greater than that of its components. Thus platinum, which is infusible in our common furnaces, forms, when combined with arsenic, a very fusible alloy; and an alloy of certain proportions of lead, tin, and bismuth is fusible at 212°, a temperature several degrees below the melting point of its most fusible constituent.

iv. Alloys are generally more oxidizable than their constituents taken singly; a property which is, perhaps, partly referable to the formation of an electrical combination. Where an alloy consists of two metals, the one easily and the other difficultly oxidizable, it may be decomposed by exposing it to the action of heat and air, the former metal being converted into an oxide; its last portions, however, are often not easily separated, being protected by combination with the least oxidable metal. An alloy of three parts of lead and one of tin is infinitely more oxidizable than either of its components, and easily burns at a dull red heat.

v. The action of acids on alloys may generally be anticipated by a knowledge of their effects upon the constituent metals; but if a soluble metal be alloyed with an insoluble one, the former is often protected by the latter from the action of an acid. Thus, silver alloyed with a large quantity of gold, resists the action of nitric acid in consequence of the insolubility of the latter metal in that acid; and, in order to render it soluble, it is requisite that it should be made to form about a fourth part of the alloy, in which case the nitric acid extracts it, and leaves the gold in an insoluble film or powder.

537. Various classifications of the metals have been adopted by chemical authors; some dependent upon their physical, others upon their chemical properties. The former can scarcely be considered as adapted to chemical inquiry, and the latter involve numerous difficulties in consequence of the gradual transition of metals of one class into those of another. I shall consider the metals in the order in which they are set down in the following Table, and which is nearly that of their respective attractions for oxygen.

1. Potassium
2. Sodium
3. Lithium
4. Calcium
5. Barium
6. Strontium
7. Magnesium

8. Manganese
9. Iron
10. Zinc
11. Tin
12. Cadmium

13. Copper
14. Lead
15. Antimony
16. Bismuth
17. Cobalt
18. Uranium
19. Titanium
20. Cerium
21. Tellurium
22. Selenium

23. Arsenic
24. Molybdenum
25. Chromium
26. Tungsten
27. Columbium

28. Nickel
29. Mercury

30 Osmium
31 Iridium
32 Rhodium
33 Palladium
34 Silver
35 Gold
36 Platinum

37 Silicium
38 Alumium
39 Zirconium
40 Glucium
41 Yttrium
42 Thorinum

Of these metals the first seven produce alcaline oxides which are very difficult of reduction; and they rapidly decompose water at all temperatures, a character which announces their powerful attraction for oxygen: the next five decompose water when their temperature is raised to redness: the ten following do not decompose water at a red heat; nor do the next five, which produce acids by uniting to oxygen. The oxides of these twenty-seven metals are not reducible by heat alone, though some of them, when heated, give out a portion of oxygen. The nine metals which next follow, osmium excepted, have a comparatively feeble attraction for oxygen; and when their oxides are heated, they are reduced to the metallic state. The last six metals are placed in the list from analogy; they are only known in the state of oxides, which have not hitherto been reduced.

SECTION I. *Potassium.*

538. THIS metal was discovered in 1807 by Sir Humphry Davy,—(*Philos. Trans.* 1808). He obtained it by submitting caustic potassa, or potash, to the action of Voltaic electricity: the metal was slowly evolved at the negative pole. By this process, however, it could only be procured in very minute quantities; and various other methods have been devised, of which the best is that described by Gay-Lussac and Thenard. (*Recherches Physico-chymiques.*) It is as follows:

539. A sound and perfectly clean gun-barrel is bent, as shown in the annexed sketch. It is then covered with an infusible lute between the letters O and E (fig. 1.) and the interior of the luted part is filled with clean iron turnings. Pieces of fused potassa are then loosely placed

Fig.1.

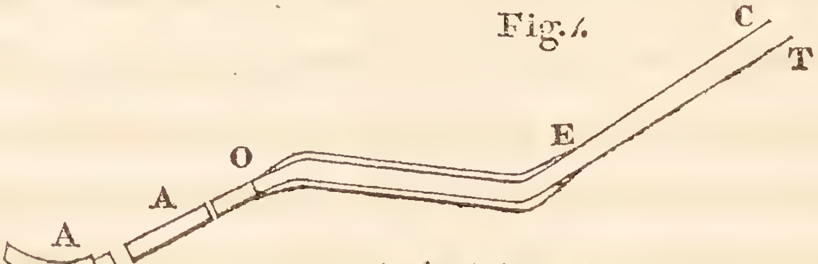
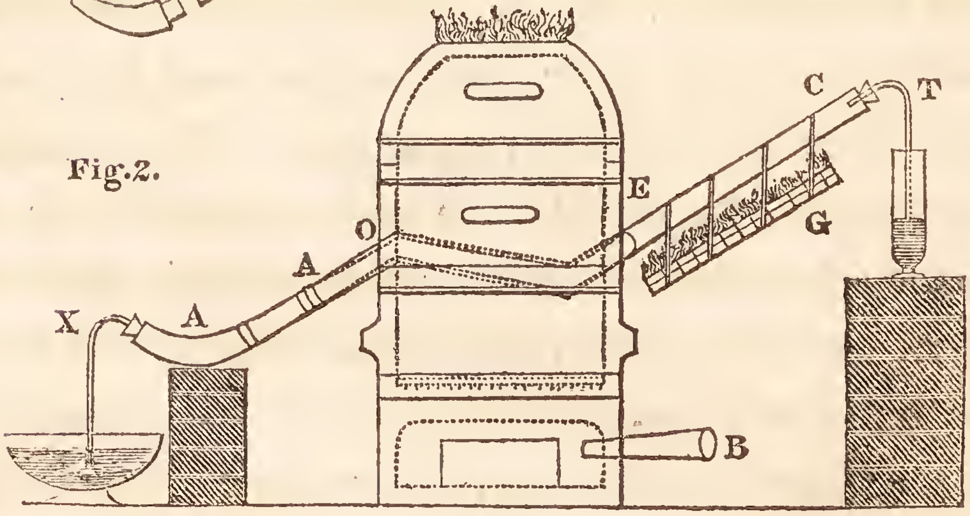


Fig.2.



in the barrel between E and C. A A is a copper tube and small receiver, which are adapted to the extremity O, and to each other, by grinding. This apparatus is next transferred to the furnace, arranged as shown in fig. 2, X and T representing two glass tubes dipping into mercury. The furnace is supplied with air by a good double bellows entering at B, and a small wire basket G, is suspended below the space E C. The part of the barrel in the furnace is now cautiously raised to a white heat, and the escape of air by the tube X shews that all is tight. Some burning charcoal is then put at the end E, of the cage G, which causes a portion of potassa to liquefy and fall into the low part of the barrel upon the iron. Hydrogen gas instantly escapes by the tube X, and attention must now be had to keep the copper tubes A A cool, by laying wet cloths upon them. When the evolution of gas ceases, fresh charcoal is placed under the potassa, and so on till the whole has passed down; if too much potassa be suffered to fall at once, the extrication of gas at X will be very violent, which should be avoided. If the space between A and O should become stopped by potassium, gas will issue by the tube T (which must always be under a greater pressure of quicksilver than the tube X), and it may be fused by applying hot charcoal to the tube, when the gas will again appear at X and cease at T. When the operation is concluded, the tubes X and T are removed, and corks quickly applied to the holes; and when the apparatus is cool, the barrel is carefully removed from the furnace, and a little naphtha suffered to run through it. The potassium is found in globules in the tube and receiver A A, and considerable portions often lodge at O.

The success of this operation is certain, if the heat has been sufficient; but the barrel, if not very carefully covered with lute, is apt to melt, and much, if not the whole, of the product is lost.

540. Potassium is a white metal of great lustre. It instantly tarnishes by exposure to air. It is ductile, and of the consistency of soft wax. Its specific gravity is 0.85. At 150° it enters into perfect fusion; and at a bright red heat rises in vapour. At 32° it is a hard and brittle solid. If heated in air it burns with a brilliant white flame. It is an excellent conductor of electricity and of heat.

541. *Potassium and Oxygen.*—When potassium is thrown into water it instantly takes fire; hydrogen gas is evolved, and *oxide of potassium*, or *potassa*, is found dissolved in the water. The quantity of hydrogen evolved in this experiment becomes the indicator of the proportion of oxygen which has been transferred to the metal; 100 parts of potassium are thus found to absorb 20 of oxygen; and if this be considered a protoxide, then $20 : 100 :: 7.5 : 37.5$,—so that 37.5 will be the number representing potassium, and $37.5 \text{ P.} + 7.5 \text{ O.} = 45$ will represent dry oxide of potassium.

542. Potassa, in the state it is usually met with in laboratories, contains a considerable portion of water, from which it may be freed by the action of iron at high temperatures, and there always remains in the barrel, after the above experiment, a large portion of *dry potassa*. It is a hard grey substance, which, by water, is slowly converted into the *hydrated oxide*, or caustic potash, which may be obtained by evaporation. This substance, after exposure to a red heat, is white and

very soluble in water; it may be considered as a compound of 1 proportional of protoxide of potassium = 45 + 1 proportional of water = 8.5, and its number = 53.5.

543. *Peroxide of Potassium.*—If the metal be heated in considerable excess of oxygen, it burns with intense heat and light, and an orange-coloured substance is obtained, which consists of 37.5 potassium + 22.5 oxygen = 60. This peroxide of potassium, when put into water, effervesces, oxygen is given off, and a solution of the hydrated protoxide is obtained. Peroxide of potassium is also formed by passing oxygen over potassa heated to redness.

544. The *hydrated protoxide* or *caustic potash* is procured in our laboratories by decomposing its carbonate by lime. The best process consists in boiling in a clean iron vessel, carbonate of potassa, (obtained by calcining tartar) with half its weight of pure quick lime, in water. The ley is strained through clean linen, concentrated by evaporation, again strained, and set by in a well-stopped bottle till it admits of being decanted clear from the sediment. The clear solution is to be evaporated to dryness. It is often cast into sticks for the use of surgeons, who employ it as a caustic, and in this state it generally contains some peroxide, and therefore evolves oxygen when dissolved in water. It is the *potassa fusa* of the *London Pharmacopœia.* It may be further purified by the action of alcohol, which dissolves the pure hydrate, and leaves earthy and other impurities; the alcohol is then driven off by heat. In this case the alcohol is always in some measure acted upon by the potassa, and a portion of carbonaceous mat-

ter deposited, so that it should be allowed to remain as short a time as possible combined with the alcali. Having obtained the dry caustic alcali by lime, it may be boiled in a silver basin with highly rectified alcohol for a few minutes, and then set by in a stopped phial; when the impurities are deposited, the alcoholic solution may be poured off and rapidly evaporated to dryness in a silver basin as before: the heat may then be raised so as to fuse the potassa, which, on cooling, should be broken up and preserved in well-closed phials.

Hydrate of Potassa thus purified is white, very acrid and corrosive, and at a bright red heat evaporates in the form of white acrid smoke. It quickly absorbs moisture and carbonic acid from the air, and at 60° one part of water dissolves two. It may be crystallized in octoedrons. It is highly alcaline, and being exclusively procured from vegetables was formerly called *vegetable alcali.* When touched with moist fingers it has a soapy feel, in consequence of its action upon the cuticle. In the fused state it produces heat when dissolved in water; but in its crystallized state it excites considerable cold, especially when mixed with snow. At a natural temperature of 30°, M. Lowitz found that equal weights of crystallized potassa and snow depressed the thermometer 45°.—*Annales de Chimie*, xxii.

545. *Chlorine and Potassium* act very energetically on each other, and produce the white compound which has been called *muriate of potash*, but which is a true *chloride of potassium*, consisting of 37.5 P. + 33.5 Ch. When potassium is heated in gaseous muriatic acid, this compound is formed, and hydrogen is evolved. It dis-

solves without decomposition in three parts of water at 60°. It crystallizes in cubes; its taste is saline and bitter. In old pharmacy it was called *salt of Sylvius*; also, *regenerated sea-salt.*

546. *Chlorate of Potassa* is formed by passing chlorine through a solution of potassa. Chloride of potassium is one of the results, the other is a salt in brilliant rhomboidal tables (formerly called oxymuriate of potash), the chlorate.

This salt is prepared, upon the large scale, by charging one or two Wolfe's bottles with solution of carbonate of potassa, and passing chlorine slowly through it: the gas is absorbed, and the liquor effervesces chiefly from the escape of carbonic acid; when this has ceased, the liquor may be put aside in a cold dark place for about 24 hours, when it will be found to have deposited a considerable portion of the crystallized chlorate, which may be taken out, drained, and purified by solution in hot water, which, during cooling again, deposits the salt in white crystalline scales. The liquor is generally of a pinkish hue, from the presence of manganese.

The taste of this salt is cooling and austere. When triturated it appears phosphorescent. When exposed to a dull red heat it decrepitates, fuses, and gives out oxygen, and chloride of potassium remains. It is soluble in 18 parts of cold and 2.5 of boiling water. It acts very energetically upon many inflammables, and triturated with sulphur, phosphorus, and charcoal, produces inflammation and explosion. A mixture of three parts of this chlorate with one of sulphur, detonates loudly when struck upon an anvil with a hammer, and even sometimes explodes spontaneously; hence it should not be kept ready mixed. Chlorate of potassa was proposed by Berthollet as a substitute for nitre in gunpowder. The attempt was made at Essone in 1788; but, as might have been expected, no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration, than it exploded with violence, and proved fatal to several people. With phosphorus the detonation is dangerously violent. These phænomena depend upon the decomposition of the chloric acid. The action of sulphuric acid upon chlorate of potassa has already been adverted to (217). If, instead of distilling the yellow mixture of the acid and chlorate with the caution there described, it be heated to about 150°, it suddenly explodes. The theory of the production of chloric oxide appears to be as follows: the sulphuric acid expels one proportional of oxygen from the chlorate, and the potassium absorbs one proportional to produce potassa, which gives rise to sulphate of potassa; the remaining four proportionals of oxygen and one of chlorine form the oxide of chlorine.

When sulphuric acid is poured upon mixtures of this salt and combustibles, instant ignition ensues in consequence of the evolution of oxide of chlorine, and when sulphuric or nitric acids are poured upon similar mixtures under water by means of a long funnel, inflammation also ensues.

A few grains of chlorate of potassa put into a teaspoonful of muriatic acid, and then diluted with water, form an extemporaneous bleaching liquor.

Chlorate of Potassa consists of one proportional of chloric acid and one of potassa, or 71 C. A. + 45 P. Its ultimate components, therefore, are

6	proportionals of oxygen.... 5 in the acid and 1 in the alcali	= 45
1	proportional of chlorine	= 33.5
1	——— potassium....	= 37.5
		116

547. *Oxychlorate of Potassa* may be formed by moistening one part of chlorate of potassa with three of sulphuric acid, and subsequently carefully heating the mass till it becomes white: in this state it consists of bisulphate and oxychlorate of potassa, which may be separated by solution and crystallization, the former being much more soluble in cold water than the latter salt.

Oxychlorate of potassa does not change vegetable colours, nor is it altered by exposure to air. It requires rather more than 50 parts of water at 60° for its solution. It is insoluble in alcohol. It crystallizes in elongated octoëdrons. When mixed with its own weight of sulphuric acid, and distilled at 280°, solution of oxychloric acid passes over. It may be decomposed by exposure to a temperature of 412°. Oxygen is given off, and chloride of potassium remains in the retort. This salt is thus found to consist of one proportional of oxychloric acid = 86 + one proportional potassa = 45, and its representative number is therefore = 131.

548. *Iodide of Potassium.* Iodine and potassium act upon each other very energetically, and a crystalline compound is obtained, white and fusible. The hydriodic acid and potassa produce a similar compound.

549. When iodine is put into solution of potassa, the results are *iodate of potassa* and iodide of potassium: the latter may be removed by alcohol.

Iodate of Potassa is a white difficultly soluble salt, which at a red heat gives out oxygen, and is converted into iodide of potassium.—Gay-Lussac, *Ann. de Chim.*, xci.

550. *Potassium and Hydrogen.*—When potassium is heated in hydrogen, it absorbs a portion of the gas, and produces a grey and highly inflammable *hydruret.* When hydrogen and potassium are passed together through a white hot tube, the gas dissolves the metal, and produces a spontaneously inflammable *potassiuretted hydrogen gas.* Both these compounds are usually formed during the operation for obtaining potassium by the gun-barrel.

551. *Nitrate of Potassa—Nitre—Saltpetre.* This salt is an abundant natural product, and is principally brought to this country from the East Indies, where it is produced by lixiviation from certain soils.

The rough nitre imported from the East Indies is in broken crystals of a brown colour, and more or less deliquescent: exclusive of other impurities, it often contains a very considerable proportion of common salt, which, re-acting upon the nitre, induces the production of nitrate of soda and chloride of potassium.

In Germany and France it is artificially produced in what are termed nitre-beds. Thenard (*Traité de Chemie Elémentaire*, Tom. ii., p. 511.) has described the French process at length. It consists in lixiviating old plaster rubbish, which, when rich in nitre, affords about five per cent. Refuse animal and vegetable matter which has putrefied in contact with calcareous soils produces nitrate of lime, which affords nitre by mixture with subcarbonate of potassa. In the same way it is abundantly produced in some parts of Spain. Exudations containing saltpetre are not uncommon upon new walls, where it appears to arise from the decomposition of animal matter contained in the mortar. It was long ago shown by Glauber, that a vault plastered over with a mixture of lime, wood-ashes, and cows' dung, soon becomes covered with efflorescent nitre, and that after some months, the materials yield, on lixiviation, a considerable proportion of that salt.

Nitre crystallizes in six-sided prisms, usually terminated by dihedral summits; it dissolves in 7 parts of water at 60°, and in its own weight at 212°. Its taste is cooling and peculiar. It consists of one proportional of acid = 50.5 + one proportional of potassa = 45. Or of

6	proportionals of oxygen	45
5	in the acid and 1 in the alcali..	
1	proportional of nitrogen......	13
1	———— potassium	37.5
		95.5

552. When exposed to a white heat, nitre is decomposed into oxygen, nitrogen, and dry potassa. It fuses at a heat below redness, and congeals on cooling into cakes called *sal prunelle.*

If the temperature of nitre be so far increased as to allow a portion of oxygen to escape, the remaining salt, as Scheele first observed, remains neutral, and in this state it has been considered as forming a *nitrite of potassa.*

Nitre is rapidly decomposed by charcoal at a red heat; and, if excess of charcoal be used, the results are carbonic oxide and acid, nitrogen, and subcarbonate of potassa, formerly called *nitrum fixum*, and *white flux.*

The old chemists used to perform this detonation in retorts connected with capacious receivers, which were generally blown to pieces; sometimes they succeeded in obtaining a little acidulated water, which they called *clyssus of nitre,* and attributed to it wonderful medical virtues.

When phosphorus is thrown upon nitre, and inflamed, a vivid combustion ensues, and a phosphate of potassa is formed. Sulphur sprinkled upon hot nitre burns and produces a mixture of sulphate and sulphite of potassa. This salt used formerly to be employed in medicine, under the name of *Glaser's polychrest salt.* Most of the metals, when in filings or powder, detonate and burn when thrown on red-hot nitre; some of the more inflammable metals produce in this way a considerable explosion.

553. A mixture of three parts of nitre, two of dry subcarbonate of potassa, and one of sulphur, forms *fulminating powder.* If a little of this compound be heated upon a metallic plate, it blackens, fuses, and explodes with much violence, in consequence of the rapid action of the sulphur upon the nitre.

554. *Gunpowder* consists of a very intimate mixture of nitre, sulphur, and charcoal. The proportions vary. The following are those usually employed:

	Common Gunpowder.	Shooting powder.	Shooting powder.	Miners' powder.
Saltpetre	75.0	78	76	65
Charcoal	12.5	12	15	15
Sulphur	12.5	10	9	20

The latter contains the smallest quantity of saltpetre, as it requires less *quickness* or *strength.* The ingredients are *perfectly* mixed, moistened, beaten into a cake which is afterwards broken up, granulated, dried, and for the finest powder polished by attrition. The violence of the explosion of gunpowder depends upon the sudden production of gaseous matter, resulting from the action of the combustibles upon the nitre. Carbonic oxide, carbonic acid, nitrogen, and sulphurous acid, are the principal gaseous results; and the solid residue consists of subcarbonate, sulphate, and sulphuret of potassa, and charcoal.—CRUICKSHANKS, *Nicholson's Journal*, iv.

Gunpowder may, it is said, be inflamed by a violent blow; if mixed with powdered glass, or any other harder substance, and struck with a heavy hammer upon an anvil, it almost always explodes.

555. *Potassium unites to Sulphur* with the evolution of much heat and light, and forms a grey compound, which, when acted upon by water, produces sulphuretted hydrogen. It consists of 37.5 P. + 15 S. = 52.5.

556. *Potassa and Sulphur*, when fused together, form a red *sulphuret of potassa. (Liver of sulphur.)* Its taste is bitter and acrid. It is deliquescent and very soluble in water, forming a yellow solution of *hydrosulphuret of potassa.* The action of the sulphuret of potassa on water is complicated, and has been variously explained. By some this is considered as a compound of *potassium* and sulphur; in which case, when acted upon by water, hydrogen is imparted to the sulphur, and oxygen to the potassium; and a sulphuret of potassa with excess of sulphur (or sulphuretted sulphuret of potassa) is formed. If we consider the sulphuret as consisting of *potassa* and sulphur, then, the oxygen as well as the hydrogen of the water, must be transferred to the sulphur, and sulphuric and sulphurous acid, and sulphuretted hydrogen, would be formed; and generally when the solutions of the *livers of sulphur* are examined, sulphate and sulphite of the alcali, are found. On the whole, however, it appears most probable, that when sulphur and the

alcalies are fused together at a high temperature, the latter undergo decomposition, and that sulphurets of their metallic bases are actually formed.---VAUQUELIN, *Ann. de Chim.*

557. *Hyposulphite of Potassa* is formed by decomposing hydrosulphuret of potassa by sulphurous acid and evaporating to a pellicle, when it forms acicular crystals, of a cooling bitter taste, and deliquescent.

558. *Sulphite of Potassa* is formed by passing sulphurous acid into a solution of potassa, and evaporating out of the contact of air. Rhomboidal plates are obtained, white, of a sulphurous taste, and very soluble. By exposure to air, they pass into sulphate of potassa.

559. *Sulphate of Potassa* is the result of several chemical operations carried on upon a large scale in the processes of the arts. It may be formed directly by saturating sulphuric acid by potassa. It is the *sal de duobus* of the old chemists: the *potassæ sulphas* of the *London Pharmacopæia.* Its taste is bitter. It crystallizes in short six-sided prisms, terminated by six-sided pyramids. The body of the prism is often wanting, and the triangular-faced dodecaëdron results. This salt dissolves in 16 parts of cold, and 5 of boiling water, and in consequence of its difficult solubility, it is thrown down in a white granular powder, when sulphuric acid is added to a moderately strong solution of potassa. Exposed to a red heat it melts, but is not decomposed. Heated with charcoal it produces sulphuret of potassa.

It consists of 1 proportional of acid = 37.5
1 ——————— alcali = 45
82.5

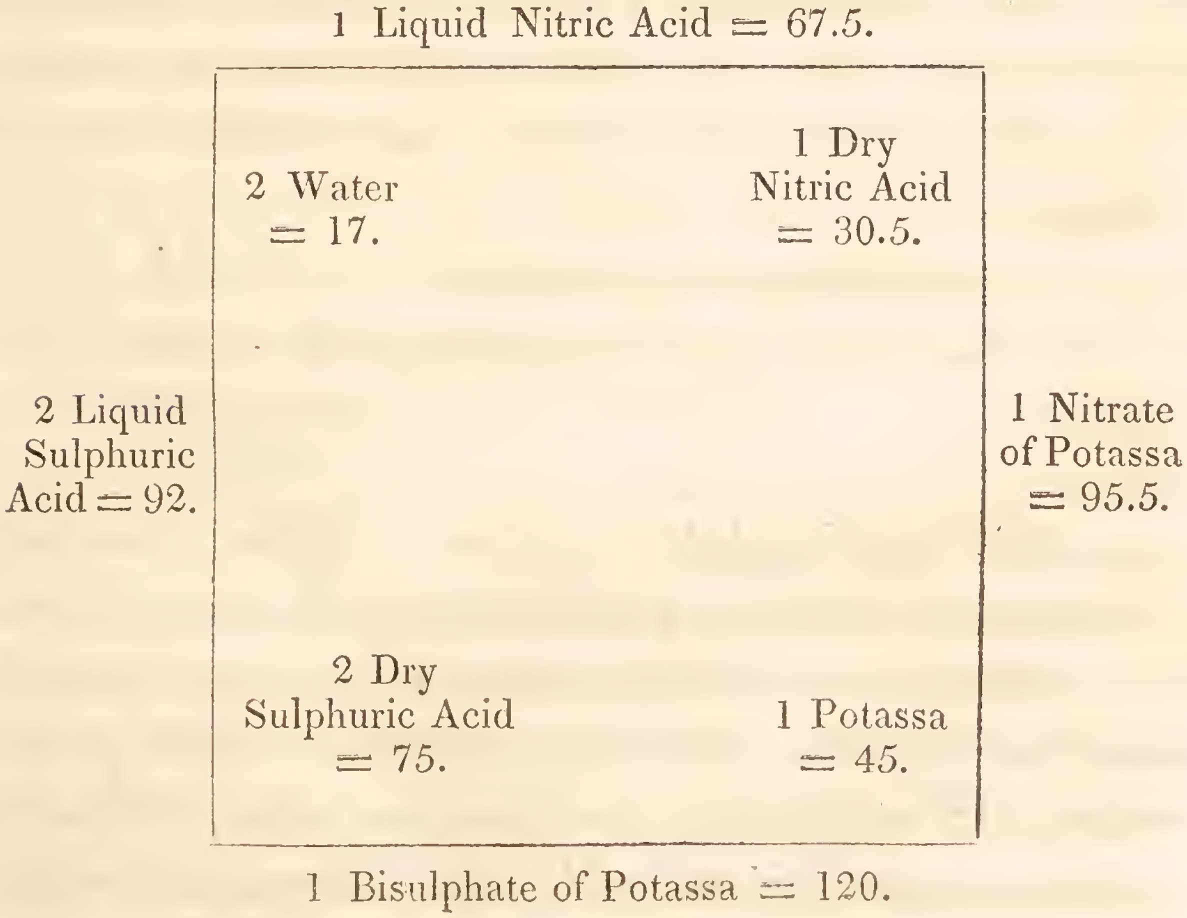
560. *Bi-sulphate* or *Supersulphate of Potassa* is formed by adding sulphuric acid to a hot solution of sul-

phate of potassa, or by boiling sulphate of potassa with sulphuric acid. The first crystals which form are in delicate needles of an acid taste, soluble in 2 parts of water at 60°, and consist of

2 proportionals of acid.. = 75
1 ——————— potassa = 45
120

Bi-sulphate of Potassa is also formed in the distillation of equal parts of nitre and sulphuric acid: nitric acid passes over, and a residuary bi-sulphate of potassa is produced, commonly known under the name of *sal enixum*. It is the *arcanum duplicatum*, or *panacea Holsatica* of old pharmaceutists. It is used for cleansing coin and other works in metal; and has a place in the *London Pharmacopœia*.

The following diagram will illustrate the formation of this salt, and of liquid nitric acid, in the distillation of two proportionals of sulphuric acid with one of nitre:



561. *Ammonio-Sulphate of Potassa* is a triple salt formed by adding ammonia to bisulphate of potassa. It crystallizes in brilliant plates of a bitter taste.—Link. *Crell's Annals*, 1796.

562. *Phosphuret of Potassium* is a brown compound, which rapidly decomposes water, producing phosphuretted hydrogen gas, and hydrophosphuret of potassa. It is formed by cautiously heating potassium with phosphorus out of the contact of air.

563. *Hypophosphite of Potassa* has been examined by Dulong. It is very deliquescent, and soluble in water and alcohol nearly in all proportions. When heated it evolves phosphuretted hydrogen and phosphorus, and is converted into phosphate of potassa.—*Annales de Chim. et Phys.*, ii. 142.

564. *Phosphite of Potassa* is a soluble deliquescent uncrystallizable salt, not hitherto accurately examined.

565. *Phosphate of Potassa* is a soluble difficultly crystallizable salt. It may be obtained by careful evaporation, in four-sided prisms, and octoëdrons. It contains

1 proportional of potassa ...... = 45
1 ——————— phosphoric acid = 26
71

566. *Subphosphate of Potassa.*—When phosphate of potassa is fused in a platinum crucible with potassa it is converted into subphosphate of potassa, which is insoluble in cold, and very difficultly soluble in hot water. It is fusible before the blow-pipe, yielding a globule, opaque when cold, but transparent whilst

in fusion. The theoretical composition of this salt is

2 proportionals of potassa = 90
1 ——————— acid = 26

567. *Superphosphate or Biphosphate of Potassa* is formed by dissolving the neutral phosphate in phosphoric acid and evaporating till crystals are obtained, which are prismatic and very soluble.

568. *Potassa and Carbonic Acid.*—These bodies combine in two proportions, forming the *carbonate* and the *bicarbonate* of potassa, compounds which have been long used and known under various names—such as *fixed nitre, salt of tartar, salt of wormwood, vegetable alcali, &c.* Their composition was first ascertained by Black. Bergman, in 1774, described their most essential properties.—*Opuscula,* Vol. i. p. 13.

569. *Carbonate of Potassa* is a salt of great importance in many arts and manufactures, and is known in commerce in different states of purity, under the names of *wood-ash*, *pot-ash,* and *pearl-ash.* It is the *subcarbonate of potassa* of the *London Pharmacopœia.*

It may be obtained directly by passing carbonic acid into a solution of potassa, evaporating to dryness, and exposing the dry mass to a red heat; or indirectly by burning *tartar,* whence the name *salt of tartar* has been applied to it.

This salt is fusible without decomposition, at a red heat: it is very soluble in water, and deliquesces by exposure to air, forming a dense solution, once called *oil of tartar per deliquium.* Its taste is alcaline, and it renders vegetable blues green. It consists of

1 proportional acid = 20.7
1 ——————potassa = 45
65.7

The great consumption of this article in various manufactures is exclusively supplied by the combustion of vegetables, and consequently its production is almost limited to those countries which require clearing of timber, or where there are vast natural forests. The English market is chiefly supplied from North America. If any vegetable growing in a soil not impregnated with sea-salt be burned, its ashes will be found alcaline from the presence of carbonate of potassa. If the ashes be submitted to heat so as to burn away the carbonaceous matter entirely, they become a white mass, generally termed *pearl-ash.*

The pearl-ash of commerce, contains a variety of impurities which render it of variable value. In general, its purity may be judged of by its easy solubility in water, two parts of which should entirely dissolve one part of the salt; the residue, if any, consists of impurities. The quantity of nitric acid of a given density, requisite to saturate a given weight, may also be resorted to as a criterion of its purity. 100 parts of nitric acid, sp. gr. 1.36, will saturate 65.7 parts of dry carbonate of potassa, which are equivalent to 45 parts of pure potassa. Upon the means of ascertaining the quantity of real alcali in the different articles of commerce, some useful observations will be found in Dr. HENRY'S *Elements of Chemistry*, ii. 512. According to Vauquelin (*Annales de Chimie*, Vol. xl.) the principal varieties of this substance used in commerce, contain the following ingredients:—

	Potash.	Sulphate of potash.	Muriate of potash.	Insoluble residue.	Carbonic Acid and water.	TOTAL.
Potash of Russia	772	65	5	56	254	1152
,, America ...	857	154	20	2	119	1152
American Pearl-ash ...	754	80	4	6	308	1152
Potash of Treves	720	165	44	24	199	1152
,, Dantzic ...	603	152	14	79	304	1152
,, Vosges	444	148	510	34	304	1440

A saturated solution of carbonate of potassa in water contains about 48 per cent. of the salt, and has a specific gravity of 1.5.

570. *Bi-carbonate of Potassa* is formed by passing a current of carbonic acid into a solution of the sub-carbonate. By evaporation crystals are obtained in the form of four-sided prisms, with dihedral summits. Their taste is only slightly alcaline, and they require for solution four parts of water, at 60°. Exposed to a red heat, carbonic acid is evolved, and carbonate of potassa remains. This bi-carbonate consists of

2 proportionals of carbonic acid = 41.4
1 ———— potassa, = 45
86.4

In its crystalline form it contains water equal to one proportional; and, therefore, consists of

86.4 carbonate
8.5 water
94.9

In the *London Pharmacopœia* the more expensive method of obtaining this salt by the action of carbonate of ammonia on carbonate of potassa is resorted to.

The following proportions may be used for the preparation of bi-carbonate of potassa upon the large scale: 100 lbs. of purified carbonate of potassa are dissolved in 17 gallons of water, which, when saturated with carbonic acid, yields from 28 to 30 lbs. of crystallized bi-carbonate; 50 lbs. of carbonate of potassa are then added to the mother liquor, with a sufficient quantity of water to make up 17 gallons, and the operation repeated.

The subcarbonate and carbonate of potassa, are both decomposed by lime, which deprives them of carbonic acid; hence the use of that earth in the process for obtaining pure *potassa.*

571. Potassium heated in cyanogen absorbs the gas, and produces a grey *cyanuret of potassium*, which by the action of water becomes *hydrocyanate of potassa.* This salt speedily decomposes and becomes converted into carbonic acid and ammonia.

572. *Borate of Potassa* is a salt which has been scarcely examined; it may be prepared by boiling boracic acid in solution of potassa, or by exposing a mixture of boracic acid and nitre to a bright red heat; it furnishes by solution and evaporation quadrangular prisms, permanent in the air.

573. The salts of potassium are soluble in water, and afford no precipitates with pure or carbonated alcalis. They produce a precipitate in muriate of platinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by

sulphuretted hydrogen, nor by ferro-prussiate of potassa. Added to sulphate of alumina, they enable it to crystallize, so as to form alum.

Section II. *Sodium.*

574. Sodium, discovered by Sir H. Davy in 1808, is obtained from soda by an operation analogous to that for procuring potassium from potassa (539). It is soft, malleable, and easily sectile. Its sp. gr. is 0.97. In colour it resembles lead. It fuses at about 190°, and is volatile at a white heat. It burns when heated in contact with air, and requires the same cautions to preserve it as potassium.

575. *Sodium and Oxygen.*—When sodium is thrown upon water, it produces violent action, but the metal does not in general inflame; hydrogen is evolved, and a solution of soda is procured. By the quantity of hydrogen evolved, we learn that *soda (toxide of sodium)* consists of about 74.6 sodium and 25.4 oxygen *per cent.;* and, if it be considered as the protoxide, the number representing the metal will be 22, and soda will consist of 22 S. + 7.5 O., and be represented by 29.5.

576. By heating sodium in oxygen, it burns vividly, and an orange-coloured *peroxide* is formed, consisting of 22 S. + 11.25 O., and which, by the action of water, evolves oxygen, and produces a solution of the protoxide.

577. *Soda*, as it usually occurs in the laboratories, is obtained from the carbonate, by the action of lime and alcohol, as described under the head *potassa* (544). It consists of 29.5 protoxide of sodium + 8.5 water, and is represented by 38. When soda is exposed to air, it soon becomes covered with an efflorescence of carbonate of soda. Its colour is grayish white, and it requires a red heat for fusion.

578. Soda is distinguished from potassa, by forming an *efflorescent* paste when exposed to the atmosphere; potassa under the same circumstances *deliquesces.* If excess of tartaric acid be added to a solution of soda there is no precipitation; but in solution of potassa it occasions a deposit of a number of minute crystals. Solution of soda occasions no precipitate when added to solution of muriate of platinum. Solution of potassa occasions a yellow precipitate in solution of platinum. In combination with acids it produces a perfectly distinct class of salt.

579. *Chloride of Sodium.*—Sodium, when heated in chlorine, burns and produces a white compound, of a pure saline flavour, soluble in 2½ parts of water at 60°, and forming cubic crystals. It has all the properties of *common salt* or *muriate of soda*, and consists of

1 proportional of chlorine	=	33.5
——————— sodium	=	22.
		55.5

This compound is decomposed, when heated with potassium: sodium and chloride of potassium are the results.

When soda is heated in chlorine, oxygen is evolved;

when heated in muriatic acid, water is formed, and in both cases chloride of sodium is the product.

580. Common salt exists abundantly in nature, both as a solid fossil and dissolved in water. Immense masses of it are found in Cheshire, where it is known under the name of *rock salt.*

581. When heated, chloride of sodium falls into pieces with a crackling noise, or *decrepitates.* At a red heat it fuses without undergoing any decomposition, and on cooling concretes into a hard white mass. It is scarcely more soluble in boiling than in cold water, and nearly insoluble in alcohol. When pure it does not alter by exposure to air; obtained by slow or spontaneous evaporation, it crystallizes in solid cubes; but when procured, as is usually the case at a boiling heat, by removing its crystals from the surface of its solution whilst evaporating, it exhibits the form of a hollow quadrangular pyramid. A concise account of the different methods of manufacturing salt will be found in AIKIN's Dictionary.—*Art. Muriate of Soda.*

582. Chloride of sodium is decomposed by moist carbonate of potassa, and chloride of potassium and carbonate of soda are the results. In the common process for obtaining muriatic acid it is decomposed by sulphuric acid. (250). In this decomposition there is a transfer of the oxygen contained in the water of the sulphuric acid to the sodium of the salt, the chlorine of which combines with the hydrogen of the water to produce muriatic acid gas. The oxide of sodium unites with the dry sulphuric acid to produce sulphate of soda. (590).

Common salt is of most extensive use as a preservative of food, and as a condiment. Glauber first obtained muriatic acid from it, and the existence of soda in it was first shown by Duhamel.

583. *Chlorate of Soda* was procured by Mr. Chenevix (*Phil. Trans.*, 1802), by the same process as chlorate of potassa, but not possessing less solubility than chloride of sodium, the two substances are difficultly separable. Vauquelin obtained it by saturating chloric acid with soda. Its crystals resemble those of chlorate of potassa, its taste is also nearly similar.

584. *Sodium and Iodine* act upon each other with the same phænomena as potassium, and an *iodide of sodium* is obtained. The hydriodic acid and soda produce a similar compound. It is deliquescent, and its solution yields quadrangular crystals.

585. *Iodate of Soda* is made by dissolving iodine in solution of soda; a white compound forms, which is the iodate with a portion of hydriodate of soda; the latter may be removed by alcohol. Iodate of soda forms small prismatic tufted crystals, which, when heated, afford oxygen and iodide of sodium.—Gay-Lussac, *Annales de Chimie*, xci.

586. *Nitrate of Soda* crystallizes in rhombs, soluble in three parts of water at 60°, and in less than its weight at 212°. It has a cool sharp flavour, and is somewhat deliquescent. It consists of 29.5 soda + 50.5 nitric acid. It is often found in crude nitre, resulting apparently from the decomposition of common salt. It is the *cubic nitre* of old writers.

587. *Sulphuret of Sodium and of Soda.* See *Potassium.* (556). The sulphurets exhibit nearly similar properties.

588. *Hyposulphite of Soda* is formed as hyposulphite of potassa. (557). It is difficultly crystallizable, deliquescent, of an intensely bitter taste, and insoluble in alcohol. Its aqueous solution readily dissolves moist chloride of silver.

589. *Sulphite of Soda* is crystallizable in transparent four and six-sided prisms, soluble in four parts of water at 60°. It consists of 29.5 soda + 30 sulphurous acid. The crystals contain twelve proportionals of water = 102.

590. *Sulphate of Soda—Glauber's Salt—Sal mirabile*—is abundantly produced in the manufacture of muriatic acid, by the action of sulphuric acid upon common salt.

Common salt consists of 22 sodium + 33.5 chlorine. Sulphuric acid consists of 37.5 dry acid + 8.5 water. The water of the acid, consisting of 1 hydrogen + 7.5 oxygen, is decomposed. Its hydrogen is transferred to the chlorine to produce gaseous muriatic acid (1 H. + 33.5 C. = 34.5 Mur. A.), and its oxygen unites to the sodium, forming dry soda (7.5 Ox. + 22 S. = 29.5 soda). The 37.5 dry acid, unite to the 29.5 soda, to produce sulphate of soda, which will be represented by the number 67.

591. Sulphate of soda crystallizes from its aqueous solution in large four-sided prisms, transparent, and efflorescent, when exposed to air. They consist of 67 dry sulphate + 85 water. Exposed to dry air, the crystals part with about 50 per cent. of water.

The taste of sulphate of soda is saline and bitter: it is soluble in rather less than three times its weight of water at 60°. When exposed to heat it undergoes watery fusion, that is, it melts in its own water of crystallization; when this has evaporated it fuses.

592. Sulphate of soda is sometimes decomposed for the purpose of obtaining soda, by igniting it with chalk and charcoal, or with iron and charcoal. (Of these processes a full account is given in Aikin's *Dictionary*, Art. *Muriate of Soda.*) Its principal use is in Pharmacy.

593. *Bi-sulphate of Soda* is obtained by adding sulphuric acid to a hot solution of sulphate of soda. It crystallizes in rhomboids soluble in twice their weight of water at 60°. This salt consists of 67 sulphate of soda + 37.5 sulphuric acid = 104.5.—Crell's *Annals*, 1796.

594. *Ammonio-sulphate of Soda* is a triple salt, formed by saturating the bi-sulphate with ammonia.—Crell's *Annals*, 1796, I.

595. *Phosphite of Soda* has not been examined. *Hypophosphite of Soda* is very soluble both in alcohol and water.—*Annales de Chim. et Phys.* ii. 142.

596. *Phosphate of Soda* crystallizes in rhomboidal prisms, soluble in four parts of water at 60°, and efflorescing when exposed. It has a pure saline taste. It consists of

29.5	soda
26	phosphoric acid
55.5	

The crystals contain about 60 per cent. of water. This salt is usually obtained for pharmaceutical purposes by saturating the impure phosphoric acid, obtained from calcined bones by sulphuric acid, (See *Phosphorus*) with carbonate of soda: the liquor is filtered, evaporated, and set aside to crystallize. It was introduced into pharmacy by Dr. Pearson; it is the *sal perlatum* of some old writers.

When heated, phosphate of soda fuses and boils up, and having lost its water of crystallization, it runs into a clear glass, which becomes opaque on cooling. If a globule be heated before the blow-pipe, it assumes the dodecaëdral figure as it cools.

597. Treated with sulphuric acid, phosphate of soda is only partly decomposed, a *bi-phosphate of soda* being formed, which is more soluble than, and not so easily crystallizable as the phosphate.

598. *Ammonio-phosphate of Soda* exists in human urine, whence it was procured by the early chemists under the names of *microcosmic* and *fusible salt.* When exposed to heat the ammonia is expelled, and a *bi-phosphate of soda* remains: it appears to consist of two proportionals of phosphoric acid = 52; one of soda = 29.5, and one of ammonia = 16.—FOURCROY, *Annales de Chimie,* vii. 183.

599. *Carbonate of Soda* is chiefly obtained by the combustion of marine plants, the ashes of which afford, by lixiviation, the impure alcali called *soda.* Two kinds of rough soda occur in the market; *barilla,* and *kelp*; besides which, some *native carbonate of soda* is also imported. Barilla is the semifused ash of the *salsola soda,* which is largely cultivated upon the Mediterranean shore of Spain, in the vicinity of Alicant. Kelp consists of the ashes of sea weeds, which are collected upon many of the rocky coasts of Britain, and burned in kilns, or merely in excavations made in the ground and surrounded by stones. It seldom contains more than 5 per cent. of carbonated alcali, and about

24 tons of sea weed are required to produce one ton of kelp. The best produce is from the hardest *fuci*, such as the *serratus*, *digitatus*, *nodosus*, and *vesiculosus*. (Mac Culloch's *Western Islands*, Vol. i., p. 122.) The rough alcali is contaminated by common salt, and other impurities, from which it may be separated by solution in a small portion of water, filtrating the solution, and evaporating it at a low heat: the common salt may be skimmed off as its crystals form upon the surface.

600. The primitive crystalline form of carbonate of soda is an octoëdron, with a rhombic base; the solid angles of the summit are always wanting, being replaced by planes parallel to the base, and thus presenting a solid with 10 surfaces. It is soluble in twice its weight of water at 60°. Its taste is strongly alcaline, and it greens vegetable blues. It consists of

29.5 soda
20.7 carbonic acid
―――
50.2

Its crystals contain seven proportionals of water = 59.5, which may be expelled by heat. They effloresce by exposure to air. This salt is the *Sodæ-Subcarbonas* of the *Pharmacopœia.*

In the analysis of barilla and kelp, to ascertain the relative proportion of soda, it may be useful to know that 100 parts of dilute nitric acid, sp. gr. 1.36, will saturate 50 parts of dry carbonate of soda, which are equivalent to about 29 of pure soda.

601. *Bi-carbonate of Soda* is formed by passing carbonic acid through the solution of the subcarbonate.

By evaporation a crystalline mass is obtained. This salt consists of

29.5	soda
41.4	carbonic acid
70.9	

The bi-carbonate of soda has a very slightly alcaline taste, and it is much less soluble in water than the sub-carbonate.

602. This salt, as well as the bi-carbonate of potassa, may be obtained by treating their respective carbonates with carbonate of ammonia; pure ammonia is evolved and bi-carbonates are formed.—See *London Pharmacopœia.*

In the manufacture of this bi-carbonate for the purpose of commerce, 160 lbs. of carbonate may be dissolved in 13 gallons of water, and carbonic acid thrown into the solution in a proper apparatus. The bi-carbonate falls as it forms to the amount of about 50 lbs., and being separated from the solution may be conveniently dried by pressure in an hydraulic press, and subsequent exposure to heat not exceeding 100°. A fresh portion of carbonate is dissolved in the mother liquor, and the operation repeated as before.

603. A mixture of the carbonates of soda occurs native in great abundance in Africa, in the province of Gahena, near Fezzan. The natives call it *Trona.* It has been analyzed by Mr. R. Phillips, who considers it as a compound intermediate between the carbonate and bi-carbonate, composed of 3 proportionals of acid and 2 of base, or 1 soda + $1\frac{1}{2}$ acid; hence he terms it a *sesqui-carbonate of soda.*—*Quarterly Journal,* vii., p. 298.

A very productive soda-lake also exists in South America in Maracaybo, one of the provinces of Venezuela.—*Quarterly Journal*, i. p. 188.

604. *Subborate of Soda—Borax.*—This salt, which has been very long known, is imported from India in an impure state, under the name of *Tincal*, which, when purified, is called *Borax*. It crystallizes in irregular hexaëdral prisms, slightly efflorescent. Its taste is alcaline and styptic. It is soluble in 20 parts of water at 60°, and in six parts of boiling water. When heated it loses water of crystallization, and becomes a porous friable mass, called *calcined borax*. It consists, according to Bergman, of

34	acid
17	soda
49	water
100	

Sulphuric acid decomposes this salt, producing sulphate of soda and boracic acid. (Chap. IV. § vi.) It has a place in the *Pharmacopœia*, and is sometimes used as a flux.

605. The salts of sodium are soluble in water. They are not precipitated either by pure or carbonated alcalis, or hydrosulphuret of ammonia, or ferro-prussiate of potassa; they produce no precipitate in solution of muriate of platinum, and do not convert sulphate of alumina into octoëdral alum.

606. Potassium and sodium form an alloy, which, if composed of one part of potassium and three of sodium, remains fluid at 32°. Equal parts of the metals form a brittle crystallizable alloy.

SECTION III. *Lithium.*

607. IN the analysis of a mineral, called *petalite,* M. Arfwedson discovered about three *per cent.* of an alcaline substance, which was at first supposed to be soda; but, finding that it required for its neutralization a much larger quantity of acid than soda, he was led to doubt its identity with that alcali, and the further prosecution of his inquiries fully demonstrated that it possessed peculiar properties. The mineral called *triphane,* or *spodumene,* also affords the same substance, to which the term *lithia,* deduced from its lapideous original, has been applied. It has also been detected in a few other minerals.

The following is the mode of obtaining lithia from the above substances:—Reduce the mineral to a fine powder, and fuse it with about half its weight of potassa; dissolve the fused mass in muriatic acid, filter, and evaporate to dryness; digest the dry mass in alcohol; the only substance present, soluble in that liquid, is the *muriate of lithia,* which is taken up, and by a second solution and evaporation is obtained pure. It may be decomposed by digesting carbonate of silver in its aqueous solution, by which a carbonate of lithia is formed, decomposable by lime, in the way of the other alcaline carbonates.

608. When lithia is submitted to the action of the Voltaic pile, it is decomposed with the same phænomena as potassa and soda; a brilliant white and highly com-

bustible metallic substance is separated, which may be called *lithium*, the term *lithia* being applied to its oxide.

The properties of this metal have not hitherto been investigated, in consequence of the difficulty of procuring any quantity of its oxide.

609. Pure lithia is very soluble in water, and its solution tastes acrid like the other fixed alcalis. It acts powerfully on vegetable blues, converting them to green. It is very sparingly soluble in alcohol.

Direct experiments upon the composition of lithia are yet wanting. By calculation from the composition of the sulphate, as analyzed by Vauquelin, it would appear to contain about 55.2 lithium + 44.8 oxygen.

610. *Chloride of Lithium*, obtained by evaporating the muriate to dryness, and fusing it, is a white semi-transparent substance. It evidently differs from the chlorides of potassium and sodium, in being extremely deliquescent; in being soluble in alcohol; in being decomposed when strongly heated in the open air, when it loses chlorine, absorbs oxygen, and becomes highly alcaline; in being very difficultly crystallizable; and in tinging the flame of alcohol of a red colour.

611. *Iodide of Lithium.*—The action of iodine, of hydriodic acid, and of iodic acid, on lithia has not been examined.

612. *Nitrate of Lithia* is a very soluble deliquescent salt, fusible and decomposed by heat; its taste is cooling; it crystallizes in rhomboids.

613. *Sulphuret of Lithium.*—The action of sulphur on lithium and lithia appears analogous to its action on potassium and potassa, but the compounds have not been precisely examined.

614. *Sulphate of Lithia* crystallizes in small rectangular prisms, perfectly white, and possessed of much lustre. Their taste is saline, and their solubility intermediate between that of sulphate of potassa and sulphate of soda. The crystals contain no water, and fuse at a heat below redness. Their solution occasions no change in solution of platinum, nor in tartaric acid. They consist of

Sulphuric acid	69.18
Lithia	30.82
	100

615. *Phosphate of Lithia* has been examined by Dr. Gmelin: it may be obtained by adding phosphoric acid to sulphate of lithia; no precipitate is at first formed, but on adding excess of ammonia, an insoluble phosphate of lithia falls. This property enables us to separate lithia from potassa and soda. The phosphate of lithia may be decomposed by dissolving it in acetic acid and adding acetate of lead: *acetate of lithia* remains in solution.

616. *Carbonate of Lithia.*—When a strong solution of carbonate of potassa is added to sulphate of lithia, a white precipitate of *carbonate of lithia* is formed. It requires about 100 parts of water at 60° for its solution. It is fusible, alcaline, effervesces with acids, and absorbs carbonic acid from the air. Lithia and its carbonate, when heated upon platinum, act upon that metal.

617. If we assume from Vauquelin's corrected analysis of the sulphate, that lithia contains 45 per cent. of oxygen and 55 of lithium, and that it is a protoxide,

then 55 : 45 :: 7.5 : 9.1. So that the number 9 might be assumed as the representative number of lithium; and oxide of lithium, or lithia, would contain—

Lithium	9	+ Oxygen..	7.5	= 16.5
Chloride of Lithium	9	+ Chlorine	33.5	= 42.5
Nitrate of Lithia—Lithia	16.5	+ Nitr. acid	50.5	= 67
Sulphate..............	16.5	+ Sul. acid	37.5	= 54
Carbonate............	16.5	+ Carb. acid	20.7	= 37.2

SECTION IV. *Calcium.*

618. WHEN lime is electrized negatively in contact with mercury, an amalgam is obtained, which, by distillation, affords a white metal. It has been called *calcium*, and when exposed to air, and gently heated, it burns and produces the *oxide of calcium*, or *lime.*

Lime appears to consist of 19 parts of this metallic base united to 7.5 parts of oxygen, so that its representative number will be = 26.5.

619. The combinations of lime are very abundant natural products, and of these the *native carbonate* which, more or less pure, constitutes the different kinds of marble, chalk, and limestone, and which is also the leading hardening principle of shell, coral, *&c.*, may be considered as the most important.

Lime may be obtained in a state of considerable purity by exposing powdered white marble to a white heat, which expels the carbonic acid. To obtain absolutely pure lime, white marble may be dissolved in dilute muriatic acid, a little ammonia added to the solution, and filtered: carbonate of ammonia is then added, and the precipitate dried, washed, and exposed to a white heat. Its colour is light grey; it is acrid and caustic, and converts vegetable blues to green; its specific gravity is 2.3; it is very difficult of fusion, but remarkably promotes the fusion of most other earthy bodies, and is therefore used in several metallurgic processes as a cheap and powerful flux. When quite pure it can only be fused in very minute particles by the oxygen blowpipe, or by the Voltaic flame. It is an essential ingredient in mortar and other cements used in building. Exposed to air it becomes white by the absorption of water and a little carbonic acid.

620. When a small quantity of water is poured upon lime, there is a great rise of temperature resulting from the solidification of a portion of the water, and a white powder is obtained, called *slacked lime*, which is a *hydrate*, and which appears to consist of one proportional of water = 8.5 + one proportional of lime = 26.5.

Lime may be obtained in a crystalline form by placing lime-water under the receiver of an air-pump, containing another vessel of sulphuric acid. The water is thus slowly evaporated, and imperfect six-sided crystals of hydrate of lime are formed.—GAY-LUSSAC, *Annales de Chimie et Phys.*, i. 334.

At the temperature of 60°, 750 parts of water are required for the solution of one part of lime.

621. Lime-water is limpid and colourless; its taste

is nauseous, acrid, and alcaline, and it converts vegetable blues to green. It is usually prepared by pouring warm water upon powdered lime, and allowing the mixture to cool in a close vessel: the clear part is then decanted from the remaining undissolved portion of lime. When lime-water is exposed to the air, a pellicle of carbonate of lime forms upon its surface, which, if broken, is succeeded by others, until the whole of the lime is thus separated in the form of an insoluble carbonate. Lime-water is used in medicine as an antacid.

622. When oxygen is passed over heated lime, it is absorbed, and a portion of *peroxide of calcium* is formed. A hydrated peroxide of calcium is thrown down, according to M. Thenard, when lime-water is dropped into oxygenated water.

623. *Chloride of Calcium* is produced by heating lime in chlorine, in which case oxygen is evolved; or by evaporating *muriate of lime*, obtained by dissolving carbonate of lime in muriatic acid, to dryness, and exposing the dry mass to a red heat in close vessels. It consists of 19 calcium + 33.5 chlorine = 52.5. This compound has a strong attraction for water; it deliquesces when exposed to air, and becomes what used to be called *oil of lime*. It is difficultly crystallizable from its aqueous solutions; with care, however, it may be obtained in six-sided prisms, consisting of the chloride combined with water. It is most readily crystallized by exposing its solution to the temperature of 32°. Its taste is bitter and acrid; one part of water at 60° dissolves four parts of the chloride. Its solubility, however, is greatly influenced by temperature, for at 32° one part of water will not dissolve more than two of the

salt, and at 212° it takes up nearly any quantity. It is copiously soluble in alcohol, and much heat is evolved during the solution. When fused it acquires a phosphorescent property, as was first observed by Homberg, and hence termed *Homberg's phosphorus.* It is abundantly produced in the manufacture of carbonate of ammonia, from the decomposition of muriate of ammonia by lime, and hence has sometimes been called *fixed sal ammoniac.* The production of cold by mixing muriate of lime with snow has already been adverted to. (81.) Chloride of lime absorbs ammoniacal gas in considerable quantities. (FARADAY, *Journal of Science,* Vol. v. p. 74.) In its fused state this compound is very useful for drying certain gaseous bodies, but where the quantity of the gas is to be ascertained, its powers of absorption in certain cases must not be overlooked.

Pelletier has stated, that if carbonic acid be passed through a solution of muriate of lime, the whole becomes a hard solid mass. If sulphuric acid be poured into a strong solution of muriate of lime, the whole congeals into a solid mass of sulphate of lime.

624. A substance called *Oxymuriate of Lime* is abundantly employed as a bleaching material, and manufactured by passing chlorine into leaden chambers containing hydrate of lime in fine powder, by which the gas is copiously absorbed. Dr. Thomson has shown this to be a compound of chlorine and lime; when heated it gives off a large quantity of oxygen, and a chloride of calcium results. This shows the superior attraction of calcium for chlorine compared to oxygen, the latter being expelled from the lime.

625. *Chlorate of Lime* is a very soluble deliques-

cent salt of a sharp bitterish taste. It is most easily produced by dissolving carbonate of lime in chloric acid. Exposed to heat, oxygen is evolved, and a chloride formed.

626. *Iodate of Lime* is difficultly crystallizable in small quadrangular prisms. *Hydriodate of Lime* is very deliquescent; when dried it becomes *iodide of calcium*, a white fusible compound.

627. *Nitrate of Lime* is a deliquescent salt, soluble in 4 parts of water at 60°. It is found in old plaster and mortar, from the washings of which, nitre is procured by the addition of carbonate of potassa. It is composed of

34.5	Lime	26.5
65.5	Nitric acid	50.5
100		77

The production of this salt in artificial nitre-beds has already been adverted to. (551). It may be crystallized in six-sided prisms. It is soluble in alcohol. When exposed to a moderate heat it undergoes watery fusion; the water then evaporates, and the salt fuses: on cooling it concretes into a semi-transparent phosphorescent substance, called from the discoverer of this property, *Baldwin's phosphorus*. At a red heat it is decomposed; its acid is dissipated, and pure lime remains. It contains in its crystallized state about 25 per cent. of water, and may hence be considered as composed of

1	proportional dry nitrate..	77
3	———— water......	25.5
		102.5

628. *Sulphuret of Lime* is formed by heating lime with sulphur. It is soluble in water with the same phænomena as sulphuret of potassa.

629. According to Mr. Herschel, crystallized *hydrosulphuret of lime* is formed when three parts of slacked lime and one of sulphur are boiled in twenty parts of water, and the solution allowed to cool upon the sediment: he dried the crystals by exposure to the absorbent power of a large surface of sulphuric acid, placed under an exhausted receiver. Their form is that of quadrilateral prisms with dihedral summits. They are sparingly soluble in cold water, the solution having a yellow colour and an acrid, bitter, and sulphurous taste. They consist of two proportionals of lime, two of sulphur, one of hydrogen, and four of water.—*Edinburgh Philosophical Journal*, i. p. 11, *&c.*

630. When sulphurous acid is ground in a mortar with the above crystals its smell disappears, and when filtered it is found to be a solution of *hyposulphite of lime.* By passing sulphurous acid through an aqueous solution of sulphuret of lime, the same product is obtained: and if the solution be filtered and evaporated, at a temperature not exceeding 140°, it furnishes crystals: the temperature of ebullition decomposes it. The crystals are little altered by air, very soluble in water, and insoluble in alcohol. They consist, according to Mr. Herschel, of

Lime	21.71
Acid	36.71
Water	41.58
	100

631. The hyposulphites of soda, potassa, and ammonia, of baryta, and of strontia, may be formed by passing sulphurous acid through the aqueous solutions of their sulphurets.

632. *Sulphite of Lime* is formed by passing sulphurous acid into a mixture of lime and warm water. It is a white powder, soluble by excess of sulphurous acid, and then separating in prismatic crystals, of difficult solubility, efflorescent, and passing into sulphate of lime by exposure to air.

633. *Sulphate of Lime* occurs native in selenite, gypsum, and plaster-stone. It is easily formed artificially, and then affords silky crystals soluble in 350 parts of water. When these, or the native crystallized sulphate are exposed to a red heat, they lose water, and fall into a white powder *(plaster of Paris)*, which, made into a paste with water, soon solidifies. Dry sulphate of lime consists of

26.5 lime
37.5 sulp. acid
64

Crystalline sulphate of lime contains two proportionals of water, and is consequently represented by 64 + 17 = 81. As sulphate of lime is more soluble in water than pure lime, sulphuric acid affords no precipitate when added to lime-water. Nearly all spring and river water contains this salt, and in those waters which are called *hard* it is abundant. It gives to them a slightly nauseous taste. At a very high temperature sulphate of lime is fusible, but it suffers no decomposition; heated with charcoal it is converted into a sulphuret. It dissolves without decomposition in dilute nitric and muriatic acids, and separates from these solutions when concentrated in long silky or transparent crystals. It is decomposed by the alcaline carbonates.

634. *Native Sulphate of Lime* occurs in various forms. The crystallized variety is usually called *selenite;* the fibrous and earthy, *gypsum;* and the granular or massive, *alabaster*. The primitive form of selenite is a rhomboidal prism of 113° 8′ and 66° 52′. The crystals are commonly transparent, and of various colours; it is softer than native carbonate of lime, and yields very easily to the nail. It is seldom found in veins, but generally disseminated in argillaceous strata. It occurs in Cumberland at Alston, and in Oxfordshire at Shotover Hill, where it is often accompanied by shells and pyrites, and appears to have resulted from their mutual decomposition. A beautiful fibrous variety is found in Derbyshire, applicable to ornamental purposes.

Massive and granular gypsum is found in this country accompanying the salt-deposits in Cheshire. It abounds at Montmartre, near Paris, and contains organic remains; sometimes it forms entire hills. In the Tyrolese, Swiss, and Italian Alps, it is found upon the primitive rocks, often of the purest white, especially at Montier, near Montblanc, and near the summit of Mount Cenis. It is turned by the lathe, and sculptured into a variety of beautiful forms, more especially by the Florentine artists.

635. There is a variety of sulphate of lime, which has been called *anhydrous gypsum*, or *anhydrite*, in reference to its containing no water. It is harder than selenite, and sometimes contains common salt, and is then called *mu-*

riacite. It is rarely crystallized, generally massive and lamellar, and susceptible of division into rectangular prisms. It has been found in Derbyshire and Nottinghamshire of a pale blue tint; sometimes it is pink or reddish, and often white. It has been found at Vulpino, in Italy, and hence called *Vulpinite.* The statuaries of Bergamo and Milan employ it, and artists know it by the name of *Marbre di Bergamo.* A compound of sulphate of lime and sulphate of soda is found in the salt-mines of New Castile, which mineralogists have described under the name of *Glauberite.*

636. *Phosphuret of Lime.*—By passing phosphorus over red-hot lime, a brown compound is produced, which rapidly decomposes water with the evolution of phosphuretted hydrogen gas. *Hydrophosphuret* and *hypo-phosphite of lime* are also formed.

The best process for obtaining this phosphuret is the following: select a green glass, or porcelain tube, closed at one end, and about 18 inches long, and one inch diameter, and carefully cover it with a clay lute containing a very little borax. Put an ounce of phosphorus broken into small pieces into the lower end, and fill it up with pieces of clean quicklime, about the size of large peas: place it in an inclined position in a furnace, so that the end containing the phosphorus may protrude, while the upper part of the tube is heating to redness; then slowly draw the cool part into the fire, by which the phosphorus will be volatilized, and passing into the red-hot lime, convert a portion of it into phosphuret. Care should be taken that no considerable portion of phosphorus escapes and burns away at the open end of the tube, which, after the process, should be corked and suffered to cool. Its contents may then be shaken upon a sheet of paper, and the brown pieces picked out and carefully preserved in a well-stopped phial; the white pieces, or those which are only pale brown, must be rejected. This compound, though called phosphuret of lime, is probably a *phosphuret of calcium.*

637. Neither the *Phosphite* nor *Hypophosphite of Lime* have been particularly examined.

638. *Phosphate of Lime* exists abundantly in the bones of animals; it is also found in the mineral world. It may be formed artificially, by mixing solutions of phosphate of soda and muriate of lime. It is insipid and insoluble in water, but dissolves in dilute nitric and muriatic acid without decomposition, and is precipitated unaltered by caustic ammonia. It is decomposed by sulphuric acid, and thus the phosphoric acid for the production of phosphorus is usually procured. (See PHOSPHORUS, Chap. IV., Sect. iv.) It consists of

26.5	lime
26	phosphoric acid
52.5	

At a very high temperature phosphate of lime fuses into an opaque white enamel.

639. *Bi-phosphate of Lime* is formed by digesting the phosphate in phosphoric acid. On evaporation a white deliquescent uncrystallizable mass is obtained, composed of one proportional of lime + two of phosphoric acid.

640. The phosphoric glass described under the head *phosphoric acid* (Chap. IV., Sect. iv.) is considered by

Dr. Thomson as a definite compound, which he has termed *quadriphosphate of lime.*—*System*, ii. 460.

641. *Native Phosphate of Lime* has by some been regarded as a *sub-phosphate*, in which case it would be composed of two proportionals of lime + one phosphoric acid. This compound occurs crystallized and massive, and is known under the names of *apatite*, *asparagus-stone*, and *phosphorite*. The crystallized variety is found in Cornwall and Devonshire, of singular beauty. Its primitive form is a six-sided prism: it also occurs in volcanic products; and, what is curious, the former is phosphorescent and the latter not. The massive variety is found in Bohemia and in Spain.

642. *Carbonate of Lime* is the most abundant compound of this earth. When lime-water is exposed to air, it becomes covered with an insoluble film of carbonate of lime, and hence is an excellent test of the presence of carbonic acid. But excess of carbonic acid re-dissolves the precipitate, producing a super-carbonate. Carbonate of lime is precipitated by the carbonated alcalis from solutions of muriate, nitrate, and sulphate of lime. Exposed to a red heat the carbonic acid escapes, and quicklime is obtained. It consists of

26.5	lime
20.7	carbonic acid
47.2	

643. Carbonate of lime occurs in nature in great abundance and in various forms. The primitive form of crystallized carbonate of lime, or *calcareous spar*, is an obtuse rhomboid of 105° 5′ and 74° 55′. Its specific gravity is 2.7. It occurs in every kind of rock,

and its secondary forms are more numerous than those of any other substance; sometimes it forms fine *stalactites*, of which some of the caverns of Derbyshire furnish magnificent specimens; it is here deposited from its solution in water acidulated by the carbonic acid, and substances immersed in this water become incrusted by carbonate of lime, when the excess of acid flies off, as seen in the *petrifying well of Matlock.* A fibrous variety of carbonate of lime, called *satin spar*, is found in Cumberland.

Another variety, originally found in Arragon in Spain, has been termed *Arragonite;* it occurs in six-sided crystals, of a reddish colour, and harder than the common carbonate. There is an acicular, or fibrous variety, found in France and Germany; and the white radiated substance, improperly called *flos ferri*, is also regarded as of the same species. Some varieties contain about 3 *per cent.* of strontia.

All the varieties of marble and lime-stone consist essentially of carbonate of lime; of these, *white granular lime-stone*, or *primitive marble*, is most esteemed; there are, also, many coloured varieties of extreme beauty. It is distinguished from *secondary lime-stone* by the absence of all organic remains, by its granularly foliated structure, and by its association with other primitive substances.

The most celebrated statuary marble is that of Paros and of Mons Pentelicus, near Athens: of these, some of the finest specimens of ancient sculpture are composed. The marble of Carrara, or Luni, on the eastern coast of the Gulf of Genoa, is also much esteemed; it is milk-white, and less crystalline than the Parian.

Many beautiful marbles for ornamental purposes are quarried in Derbyshire, and especially the black marble, called also *Lucullite*. Westmoreland and Devonshire also afford beautiful varieties, and in Anglesea, a marble intermixed with green serpentine is found, little inferior in beauty to the *verd antique.*

Among the inferior lime-stones, we enumerate many varieties, such as *common marble ; bituminous lime-stone,* abundant upon the Avon, near Bristol, and known under the name of *swine-stone* or *stink-stone,* from the peculiar smell which it affords when rubbed: *Oolite* or *Roestone,* of which the houses of Bath are built; and its variety, called *Portland stone : Pisolite* consists of small rounded masses, composed of concentric layers, with a grain of sand always in the centre: and, lastly, *chalk* and *marl.*

All these substances are more or less useful for ornamental purposes, or for building; they afford quicklime when burned, and in that state are of great importance as manures, and as ingredients in the cements used for building. There is a great variety of limestones used for burning into *quicklime,* and, generally speaking, any of the varieties may be used which neither fuse nor crumble into powder at the temperature required to expel the carbonic acid, which is a full red heat.

644. *Borate of Lime* is a white tasteless powder of very difficult solubility in water.

645. The salts of lime have the following properties: —

Those which are soluble are not altered by pure ammonia, but they are decomposed by potassa and soda. They are also decomposed by the carbonates of potassa, soda, and ammonia, which produce precipitates of carbonate of lime.

Oxalate of ammonia produces in their solutions a white insoluble precipitate of oxalate of lime, which, exposed to a red heat, affords pure lime.

The insoluble salts of lime are decomposed by being boiled with carbonate of potassa, and afford carbonate of lime.

646. *Fluor Spar—Fluate of Lime.*—These terms have been applied to a body containing a peculiar principle which has not hitherto been obtained in an insulated state.

It is a principle which probably belongs to the acidifying electro-negative supporters of combustion, and which in fluor spar is, perhaps, united to calcium. It appears to be united with hydrogen in the *fluoric* or *hydrofluoric* acid. This supposed base has been called *fluorine* by Sir H. Davy; and *phtore* (from φθόριος, *destructive*,) by M. Ampére.

647. Fluor Spar is a mineral found in many parts of the world, but in great beauty and abundance in England, and especially in Derbyshire. Here it is commonly called *Derbyshire spar*, or by the miners of that county *blue John*. It is usually found in cubic crystals, which may easily be cleaved into octoëdra, sometimes considered as its primitive form (27). Its colours are extremely various. Its sp. gr. 3. It phosphoresces when exposed to a heat a little below redness. It generally occurs in veins; in the Odin mine at Castleton in Derbyshire, it is found in detached masses, from an inch to more than a foot in thickness; their structure is divergent, and the colours, which are various, disposed in concentric bands. It is the only variety which admits of being turned in the lathe into vases and other ornamental articles.

Compact fluor is a scarce variety: the finest specimens come from the Hartz. A third variety is *chlorophane*, so called from the beautiful pale green light which it exhibits when heated.

The nature of the colouring matter of fluor spar is not exactly understood. It is liable to fade, and the blue varieties become red and brown by heat.

618. *Hydrofluoric acid* (*hydrophtoric* of Ampere) is procured by distilling a mixture of one part of the purest fluor spar in fine powder, with two of sulphuric acid; the distillatory apparatus and receiver should be of lead or silver, for glass is instantly acted on; the heat required is not considerable; sulphate of lime remains in the retort, and a highly acrid and corrosive liquid passes over, which requires the assistance of ice for its condensation.

This acid is colourless, of a very pungent smell, and extremely destructive. If applied to the skin it instantly kills the part, producing extreme pain, and extensive ulceration. At 80° it becomes gaseous; it has never been frozen; it produces white fumes when exposed to a moist air, and occasions a hissing noise when dropped into water.

This acid acts upon potassium and sodium, and some other metals, with great energy; hydrogen is evolved, and a peculiar compound, probably of the basis of the acid, and the metal, results. These compounds might be called *fluorides*. The principal *hydrofluates*, or *fluates*, have been examined by Gay-Lussac and Thenard. *(Recherches Physico-chimiques.)* They have not been analyzed, but if we adopt the number 16 as the representative of the acid, considering it as composed of 15 fluorine + 1 hydrogen, it is probable that they consist of one proportional of acid and one of base.

619. *Hydrofluate of Ammonia* is not crystallizable, and when evaporated loses a portion of alcali and becomes sour; when heated it rises in a dense white vapour.

620. *Hydrofluate of Potassa* is a very soluble deliquescent, and difficultly crystallizable salt, of a sharp taste. When heated it first loses its water of crystallization, then fuses (becoming *fluoride of potassium?*) Sulphuric acid separates the hydrofluoric.

621. *Hydrofluate of Soda* has less taste, and is less soluble than the preceding. When heated it decrepitates, then fuses. It is permanent in the air, and separates from its solution in hot water, partly as a transparent pellicle and partly in crystals.

622. When hydrofluoric acid is poured into solutions of the salts of lime, a white insoluble powder is thrown down, which resembles fluor spar in its chemical properties, and must therefore be considered as a *fluoride of calcium.*

623. The hydrofluoric is the only acid that acts rapidly on glass, and cannot therefore be preserved in vessels of that material. If a plate of glass, covered with wax, having any device traced upon it by a blunt graver, be exposed to the fumes of this acid, the glass presents the appearance of having been etched, upon removing the wax.—See *Silicated fluoric Acid*, Sect. xxxvii.

624. *Fluoboric Acid.*—This is probably a compound of fluorine with boron, and if regarded as consisting of one proportional of each of its components, its representative number will be 20, and it will contain

15 fluorine + 5 boron. It is gaseous, and may be obtained by heating in a glass retort twelve parts of sulphuric acid, with a mixture of one part of fused boracic acid and two of fluor spar, reduced to a very fine powder. The gas must be received over mercury: 100 cubical inches weigh 72.5 grains ; so that the specific gravity of fluoboric acid, compared with hydrogen, is 32.22, and with atmospheric air, 2.400. It produces very copious fumes when suffered to escape into a moist atmosphere; when acted upon by water, which dissolves 700 times its volume, it affords a solution of hydrofluoric and boracic acids, whence it would seem that the hydrogen is transferred to the fluorine, and the oxygen to the boron. It acts with great energy on vegetable and animal bodies, depriving them of moisture and hydrogen. A piece of paper introduced into fluoboric gas becomes instantly charred. Potassium heated in this gas occasions the deposition of boron, and the production of fluoride of potassium, which by the action of water becomes hydrofluate of potassa.

625. The fluoboric acid combines with different bases, and produces a class of salts which have been called *fluoborates:* of these the *fluoborate of ammonia* has been examined by Dr. John Davy. (*Phil. Trans.* 1812.) It appears from his experiments that the fluoboric acid is capable of condensing successively, one, two, and three volumes of ammonia. The first is a white solid, volatile in close vessels by the application of a gentle heat. The two other compounds are liquid, and when exposed to the atmosphere, lose ammonia and pass into the first.

SECTION V. *Barium.*

626. To obtain this metal, the earth baryta is negatively electrized in contact with mercury; an amalgam is gradually formed, from which the mercury may be expelled by heat, and the metal barium remains; appearing, according to Sir H. Davy, of a dark grey colour, and being more than twice as heavy as water. It greedily absorbs oxygen, and burns with a deep red light when gently heated, producing the oxide of barium.

627. *Oxide of Barium, Baryta,* or *Barya,* is obtained by exposing the crystals of nitrate of baryta for some time to a bright red heat. It is of a grey colour, and very difficult of fusion; it appears to consist of 65 barium + 7.5 oxygen, and is, consequently, represented by 72.5. Its sp. gr. is about 4, hence the name *Baryta,* as being the heaviest of the substances usually called earths. It eagerly absorbs water, heat is evolved, and a white solid is formed, containing about 10 per cent. of water, which it retains at a red heat; this is the *hydrate of baryta,* and may be considered as a compound of 1 proportional of baryta = 72.5 + 1 proportional of water = 8.5, and is, consequently, represented by 81.

628. *Hydrate of Baryta* dissolves in boiling water, and, as the solution cools, deposits flattened hexagonal prisms, which contain a larger quantity of water, and are easily fusible. According to Mr. Dalton, crystallized ba-

ryta consists of 1 proportional of baryta and 20 of water; if it be exposed to air it effloresces into a white powder, containing 1 proportional of baryta and 5 of water; it appears therefore that there are three hydrates of baryta. (*New Chem. Phil.*, ii. 522.) The aqueous solution, or *baryta water*, is limpid, colourless, and acts energetically on vegetable blues and yellows, changing them to green and red; it rapidly absorbs carbonic acid, and deposits an insoluble carbonate of baryta. As baryta, like the alcalis, converts vegetable blues to green, and serves as an intermede between oil and water, it has been called an *alcaline earth.* It has a very acrid caustic taste, and is highly poisonous. It exists in two natural combinations only, namely, as sulphate and carbonate.

629. When baryta is heated in oxygen, or when oxygen is passed over baryta heated to redness in a glass tube, the gas is absorbed and a grey compound is obtained, which is the *peroxide of barium;* consisting of

1 proportional of barium = 65
2 ——————— oxygen = 15
80

630. By dissolving peroxide of barium in muriatic acid, and precipitating by sulphuric acid, M. Thenard succeeded in obtaining a new and singular compound of oxygen and water, to which the term *peroxide of hydrogen* may be applied. The solution of the peroxide of barium, and the subsequent separation of the protoxide is repeated a sufficient number of times, in the same portion of dilute muriatic acid; sulphate of silver is then added to separate the muriatic acid, and the sulphuric, which then becomes its substitute, is ultimately removed

by baryta. M. Thenard, in his elaborate essay upon this new compound, has shown that the process, although in theory sufficiently simple, presents many practical difficulties, chiefly arising from the impurities contained in the peroxide of barium. To obtain this substance pure, upon which the success of the subsequent operations depends, he gives the following directions. Prepare a very pure nitrate of baryta, and decompose it by a strong heat in a porcelain vessel, by which baryta, containing a portion of silica and alumina, but free from manganese, will be obtained; the latter impurity must always be most cautiously avoided, for oxide of manganese possesses the property of energetically decomposing the oxygenated water.

The baryta, broken into small pieces, is then introduced into a luted glass tube (the glass should not contain lead) large enough to contain about two pounds of it, and being heated to dull redness, a current of dry and perfectly pure oxygen gas is passed through it, which it rapidly absorbs; this operation is to be continued till the oxygen escapes from a small tube inserted into the opposite extremity of the larger one.

The peroxide thus obtained is pale grey, and frequently some pieces are speckled with green, which announces the presence of manganese, and which should be rejected: its distinctive character is, that it crumbles when a few drops of water are added to it, without producing heat.

The process then proceeds as follows. Take a certain quantity of water (about eight ounces for instance), and add to it a sufficiency of pure and fuming muriatic acid to dissolve about 230 grains of baryta: put this acid liquor into a glass vessel, which during the operation must be surrounded by ice: then take about 185 grains of the peroxide, rub it into a fine paste with a little water in an agate mortar, and put it into the acid liquor with a box-wood spatula; it soon dissolves without effervescence: to this solution add pure sulphuric acid drop by drop, stirring it with a glass rod, till it is in slight excess, which is known by the readiness with which the sulphate falls: then dissolve a second portion of the deutoxide and precipitate as before, taking care to use enough but not too much sulphuric acid. The liquor is now to be filtered, and the residue washed with a little water, so as to keep up the original measure by adding it to the first portion: a second and third washing of the residue with very small quantities of water may be advisable, and these liquors should be kept apart for the purpose of washing the filters in subsequent operations.

A fresh portion of the peroxide is then dissolved in the filtrated liquor and decomposed as before, filtering at every two operations, and washing the filter with the savings of the others. We thus proceed till the water is sufficiently oxygenated: when about two pounds of the peroxide have been consumed, the water will be united to about thirty times its volume of oxygen, which is as much as it will retain, unless some muriatic acid be added, in which case M. Thenard has made it retain 125 volumes.

When the water is sufficiently oxygenated, it is retained in the ice, and supersaturated with the peroxide of barium, which occasions the separation of flocculi of silica and alumina, coloured with a little oxide of iron and of manganese; the whole is then filtered as quickly as possible, and returned into the vessel surrounded by ice, the baryta is separated by sulphuric acid, and pure sulphate of silver is added to separate the muriatic acid, upon which the liquid, before milky, becomes suddenly clear. The sulphuric acid is ultimately separated by baryta, the liquor filtered and placed in a shallow vessel, under the air-pump receiver, containing a basin of sulphuric acid; the receiver being exhausted, the water evaporates and is absorbed by the acid, while the peroxide of hydrogen being less vaporisable remains; if it give out any oxygen, which sometimes happens from its containing impurities, a drop or two of weak sulphuric acid prevents its further evolution.

The peroxide of hydrogen thus concentrated has the following properties: its sp. gr. is 1.45; it is colourless and inodorous; it blisters the cuticle of the tongue, and has a peculiar metallic taste. It does not congeal when exposed to cold, unless diluted. It is rapidly decomposed at a heat below 212°, and very slowly at ordinary temperatures; it may be long kept at 32°. It is decomposed by the pile with the same phænomena as water. It is decomposed by all metals except iron, tin, antimony, and tellurium: the metals should be finely divided, or in powder: silver and oxide of silver decompose it very suddenly with the evolution of heat and light: platinum and gold produce the same phænomena; lead and mercury slowly separate the oxygen. Orpiment and powdered sulphuret of molybdenum act upon it with the same violence as silver; the peroxides of manganese and of lead, also, occasion its instant decomposition.

631. *Chloride of Barium* may be obtained by heating baryta in chlorine, in which case oxygen is evolved: or more easily, by dissolving carbonate of baryta in diluted muriatic acid. By evaporation, tabular crystals are obtained, soluble in 5 parts of water at 60°; and consisting, when dry, of 65 barium + 33.5 chlorine = 98.5. Its taste is pungent and acrid; when exposed to heat, the water of crystallization separates, and the dry chloride enters into fusion. It is insoluble in alcohol.

632. *Chlorate of Baryta* is formed in the same way as chlorate of potassa (546). It crystallizes in quadrangular prisms, soluble in four parts of water, at 60°. It consists of

1 proportional of baryta = 72.5
1 ——— chloric acid = 71
143.5

Or of 1 proportional of barium = 65
6 ——— oxygen = 45
1 ——— chlorine = 33.5
143.5

Gay-Lussac procured chloric acid (221) by the action of sulphuric acid upon this salt.

633. *Iodide of Barium* is easily formed by acting upon baryta by hydriodic acid, and evaporating the solution. It may also be formed by heating baryta in hydriodic gas; water and iodide of barium are the results.

634. *Iodate of Baryta* is a very difficultly soluble compound; the *hydriodate* is crystallizable and very soluble.

635. *Nitrate of Baryta* may be produced by dissolving the native carbonate in nitric acid, evaporating to dryness, re-dissolving, and crystallizing; it forms permanent octoëdral crystals. Its taste is acrid and astringent. It is soluble in 12 parts of cold and 4 of boiling water; it is decomposed by a bright red heat, furnishing pure baryta. It consists of

72.5	baryta
50.5	nitric acid
123	

The crystals contain two proportionals of water, or 123 dry nitrate + 17 water.

If a moderately strong solution of the nitrate of baryta be added to nitric acid, a precipitation of nitrate of baryta takes place, in consequence of the abstraction of water by the acid; hence in using nitrate of baryta as a test of the presence of sulphuric acid in nitric acid, (277) the latter should be considerably diluted previous to its application.

636. *Sulphuret of Barium* is a brown compound, which acts upon water as already described, producing *hydrosulphuret of baryta.*

637. *Hyposulphite of Baryta.*—This salt is thrown down on pouring muriate of baryta into a solution, not too dilute, of hyposulphite of lime; it is a white powder soluble without decomposition in muriatic acid; at a low heat it takes fire and the sulphur burns off. When the solutions from which it is precipitated are dilute, it falls, after some minutes, in small crystalline grains, followed by a copious separation of the salt.—HERSCHEL, *Edinburgh Philosophical Journal*, i. 20.

638. *Sulphite of Baryta* is insoluble in water, and formed by adding sulphite of potassa to muriate of baryta.

639. When sulphurous acid gas is passed into water holding peroxide of manganese in suspension, a neutral solution is obtained, composed of sulphate and hyposulphate of manganese. These salts are decomposed by excess of baryta, and a soluble *hyposulphate of baryta* is formed, through which carbonic acid is passed, in order to saturate any excess of baryta; and the whole being heated to drive off carbonic acid which holds a little of the carbonate in solution, the hyposulphate of baryta is obtained, and may be purified by crystallization. The solution of this salt may be decomposed by the careful addition of sulphuric acid, and the *hyposulphuric acid* is thus obtained in solution.

This acid is inodorous, sour, and may be concentrated by exposure to a vacuum with sulphuric acid: it is decomposed by a heat below that of boiling water, sulphurous acid is disengaged, and sulphuric acid remains. It perfectly saturates bases, and forms soluble salts with baryta, strontia, lime, oxide of lead, and probably with all other bases. (*Annales de Chim. et Phys.* x. 312.) The hyposulphate of baryta crystallizes in quadrangular prisms variously terminated; 100 parts of water at 60° dissolve about 14 parts. It consists of

1 proportional of baryta .... = 72.5
1 ———————— hyposulphuric acid = 67.5
2 ———————— water 8.5 × 2... = 17
157

Or it may be stated as containing in its dry state

1 baryta	= 72.5
1 sulphuric acid	= 37.5
1 sulphurous acid	= 30
	140.0

640. *Sulphate of Baryta* is an abundant natural product; it is insoluble, and therefore produced whenever sulphuric acid or a soluble sulphate, is added to any soluble salt of baryta; hence the solutions of baryta are accurate tests of the presence of sulphuric acid. Sulphate of baryta consists of one proportional of sulphuric acid and one of baryta.

37.5	sul. acid
72.5	baryta
110	

641. *Native Sulphate of Baryta, Heavy Spar,* or *Baroselenite,* is principally found in the mines of Westmorland and Cumberland, and in Transylvania, Hungary, Saxony, and Hanover. A variety met with in Derbyshire, is called *cawk.* It occurs massive, and crystallized in a great variety of forms. Its primitive figure is a rhomboidal prism, the angles of which are 101° 42′, and 78° 18′. It is harder than carbonate of lime, but not so hard as fluate of lime. Its sp. gr. is 4.7.

When native sulphate of baryta is heated it decrepitates, and at a high temperature fuses into an opaque white enamel: it was employed in the manufacture of *jasper ware* by the late Mr. Wedgwood. When formed into a thin cake with paste, and heated to redness, it acquires the property of phosphorescence. This was first ascertained by Vincenzo Cascariolo, of Bologna, whence the term *Bologna phosphorus* is applied to it. (186). The artificial sulphate of baryta is used as a pigment, under the name of *permanent white.* It is very useful for marking phials and jars in a laboratory. Sulphate of baryta is sparingly soluble in sulphuric acid.

642. As the native sulphate is a common and abundant compound, several processes have been contrived for obtaining from it pure baryta. This may be effected by reducing the crystallized sulphate to a fine powder, and heating it red hot for half an hour in a silver crucible with three parts of carbonate of potassa: the fused mass is then boiled repeatedly in water, till it no longer affords any thing soluble in that liquid; the insoluble residue, consisting chiefly of carbonate of baryta, may be digested in dilute nitric acid, by which nitrate of baryta is formed, and which will yield the pure earth by exposure to heat as above-mentioned. (635).

Another method consists in exposing to a red heat, in an earthen crucible, a mixture of six parts of finely powdered sulphate of baryta, with one of powdered charcoal, for half an hour. This converts the sulphate into sulphuret of baryta, which is to be dissolved in hot water, the solution filtered and mixed with solution of carbonate of soda as long as it occasions a precipitate, which when washed and dried, is carbonate of baryta. Or, by adding muriatic acid to the liquid sulphuret, sulphur is thrown down and sulphuretted hydrogen evolved, and muriate of baryta formed, which may be filtered off, and if required, decomposed by carbonate of potassa. Or the sulphuret, as it comes out of the crucible, may be thrown into dilute nitric acid, by which sulphuretted hydrogen is evolved, and a nitrate of baryta formed, which may be separated from the remaining impurities by copious washings with hot water.

643. *Phosphuret of Barium* is produced by passing phosphorus over heated baryta; there is an intense action and a phosphuret of a metallic lustre is obtained, which acts upon water, and affords a solution containing *Hypophosphite of Baryta.*—See Chap. IV., Sect. iv.

644. *Hypophosphite of Baryta,* like the other hypophosphites, is very soluble and scarcely crystallizable.

645. *Phosphite of Baryta* was obtained by Berzelius by adding muriate of baryta to phosphite of ammonia; a crust of phosphite of baryta was formed in 24 hours, consisting of

Phosphorous acid	24.31
Baryta........	67.24
Water	8.45

Ann. de Chim. et Phys., ii. 231.

646. *Phosphate of Baryta* consists of

26	phosphoric acid
72.5	baryta
98.5	

It is insoluble in water; and, therefore, formed by adding a solution of phosphoric acid or phosphate of soda to nitrate or muriate of baryta.

Berzelius has described a crystallizable *Bi-phosphate of Baryta,* obtained by digesting the phosphate in phosphoric acid; and a *Sesquiphosphate,* obtained by pouring the bi-phosphate into alcohol, which occasions a precipitate of a white tasteless powder, composed of 1 proportional of baryta + 1.5 proportional of acid.

647. *Carbonate of Baryta* is found native. Artificially produced, it is a white compound insoluble in water, containing

20.7	carb. acid
72.5	baryta
93.2	

It is poisonous.

648. *Native Carbonate of Baryta* was first discovered at Anglesark, in Lancashire, by Dr. Withering, and hence acquired the name of *Witherite.* It has also been found in Wales, Cumberland, Durham, Westmorland, and Shropshire. Its primitive crystal is an obtuse rhomboid: sometimes it forms pyramidal six-sided prisms. That found in Lancashire is in globular masses of a radiated structure. It is useful as a source of pure baryta and its salts, and though not soluble in water, is poisonous. It dissolves very sparingly in solution of carbonic acid, whence the superiority of baryta water to lime water in some cases as a test of carbonic acid. The native carbonate of baryta is much more difficult of decomposition by heat than the artificial; if mixed with a little charcoal powder, and kept for some time in a red heat, carbonic oxide escapes, and pure baryta is formed.

649. *Borate of Baryta* is an insoluble white powder.

650. The soluble barytic salts furnish white precipitates of carbonate and sulphate of baryta, upon the addition of carbonate or sulphate of soda. They give

a yellow tinge to the flame of spirit of wine. The sulphate is insoluble in nitric acid and in the alcalis, and very sparingly soluble in sulphuric acid.

Nearly all the barytic compounds are poisonous; the safest antidote is solution of sulphate of soda, or dilute sulphuric acid. (ORFILA, *Traité des Poisons*, Tom. i. 2me. p. 167.) The muriate of baryta has been employed in medicine, but the principal use of baryta is in the chemical laboratory. It is possible that pure baryta might be economically used for the decomposition of sulphate of soda, to obtain the pure alcali.

SECTION VI. *Strontium.*

651. THIS metal is procured from the earth strontia by the same process as barium, which metal it resembles in appearance.

652. *Oxide of Strontium,* or the earth *Strontia,* is procured by the ignition of the pure nitrate; it is of a grey colour and very difficult of fusion when free from water; it forms a *pulverulent,* and a *crystallized hydrate.* Strontia consists of

$$\begin{array}{rl} 44.5 & \text{strontium} \\ 7.5 & \text{oxygen} \\ \hline 52 & \end{array}$$

These proportions are theoretically deduced from the sulphate, for 52 parts of strontia combine with 37.5

parts of sulphuric acid, containing 15 sulphur and 22.5 oxygen; hence 7.5, or one third of the oxygen existing in the acid, must be contained in the base (527), and 52 — 7.5 = 44.5, the proportion of metal in the protoxide, and the representative number of strontium.

The *pulverulent hydrate* contains

52	strontia
8.5	water
60.5	

At the temperature of 60°, 2 parts of water dissolve 3 of the crystallized hydrate.

1 part of strontia requires about 160 of water at 60° for its solution. *Strontia water* is transparent and colourless; it greens vegetable blues, and its taste is styptic and acrid.

653. *Chlorine and Strontium.*—This compound which has also been called *Muriate of Strontia,* is commonly procured by dissolving carbonate of strontia in muriatic acid. It crystallizes in slender six-sided prisms, soluble in twice their weight of water, at 60°. When chlorine is made to act upon strontia, it is absorbed, and oxygen evolved: the resulting compound contains

44.5	strontium
33.5	chlorine
78	

It is of a grey colour. It dissolves in alcohol, and the solution burns with a purple-coloured flame.

654. *Chlorate of Strontia* is a very soluble and deliquescent salt, difficultly crystallizable, and detonates when thrown upon red-hot coals with a beautiful purple light.

655. *Iodide of Strontium* may be formed as iodide of barium. Dissolved in water, and carefully evaporated, it furnishes delicate prismatic crystals of *Hydriodate of Strontia,* which, heated in close vessels, fuses and becomes iodide of strontium by loss of water.

656. *Iodate of Strontia* is a very difficultly soluble compound; it is resolved at a red heat into oxygen, iodine, and strontia.

657. *Nitrate of Strontia* crystallizes in octoëdra and dodecaëdra; it is soluble in its weight of water at 60°. It consists of

52	strontia
50.5	nitric acid
102.5	

Its taste is pungent and cooling. At a red heat the acid is evolved and partly decomposed, and strontia remains.

This salt is used in the *red fire* employed at the theatres, which consists of 40 parts of dry nitrate of strontia, 13 of powdered sulphur, 5 of chlorate of potassa, and 4 of sulphuret of antimony. The chlorate and sulphuret should be separately powdered, and mixed together on paper with the other ingredients; a very small quantity of powdered charcoal may also be added.

658. *Sulphuret of Strontium* may be formed by fusing strontia and sulphur in a green glass tube; or by exposing the powdered sulphate to a red heat with charcoal. It dissolves in water with the same phænomena as sulphuret of potassa, and its solution furnishes, by cautious evaporation, crystals of *hydrosulphuret of strontia.*

659. *Hyposulphite of Strontia* is formed by passing sulphurous acid into the liquid sulphuret: it crystallizes in rhomboids permanent at common temperatures and soluble in about 5 parts of water at 60°. (Gay-Lussac, *Annales de Chimie*, lxxxv.) According to Mr. Herschel, this salt is doubly refractive. Its taste is bitter, and it is insoluble in alcohol.

660. *Sulphite of Strontia* has not been examined.

661. *Sulphate of Strontia* occurs native. It is nearly insoluble, 1 part requiring 4000 of water for its solution. When heated with charcoal, its acid is decomposed, and *sulphuret of strontia* is formed, which affords nitrate by the action of nitric acid. This process, equally practicable upon sulphate of baryta (642), is sometimes adopted to obtain the earth. Sulphate of strontia dissolves in hot sulphuric acid, but is thrown down upon adding water. It consists of

52	strontia
37.5	acid
89.5	

662. The *Native Sulphate of Strontia* is sometimes of a blue tint, and has hence been called *celestine*. Sometimes it is colourless and transparent. Its primitive form is a prism of 104° 48′ and 75° 42′ with a rhomboidal basis. It has been found at Strontian in Argyleshire; in the vicinity of Bristol; and at Montmartre near Paris. The finest crystallized specimens are accompanied with native sulphur, from Sicily. Its specific gravity is 3.2.

663. *Hypophosphite of Strontia* has been examined by Dulong: it is a very soluble and difficultly crystallizable salt.

664. *Phosphite of Strontia* has not been examined.

665. *Phosphate of Strontia* is an insoluble white salt, containing

52	strontia
26	acid
78	

It is soluble in excess of phosphoric acid, which is not the case with phosphate of baryta. It is entirely decomposed by sulphuric acid. By igniting it with charcoal, *phosphuret of strontium* is obtained.

666. *Carbonate of Strontia* exists native. Artificially formed, it is a white insoluble body, containing

52	strontia
20.7	carbonic acid
72.7	

When strongly heated with a little charcoal powder, it is decomposed, carbonic oxide is given off, and pure strontia remains.

667. *Native Carbonate of Strontia* or *Strontianite* is a rare mineral. It has a greenish tint, and occurs in radiated masses, and sometimes in acicular and hexaëdral crystals. It was first discovered in 1787 at Strontian in Argyleshire, whence the name of this earth; it has also been found in Saxony and in Peru. Its specific gravity is 3.6.

This substance was first examined, and the peculiarities of strontia pointed out, by Professor Hope of Edinburgh, in 1791. His experiments are detailed in the *Philosophical Transactions of the Royal Society of Edinburgh,* Vol. iv. p. 44.

668. *Borate of Strontia* was formed by Dr. Hope. It is a white powder soluble in 130 parts of water.

669. There is in many respects a resemblance between strontia and baryta, which has led to confusion in analyses.

The following are some of the most striking points of resemblance. They are both found native in the states of sulphate and carbonate only; both sulphates are soluble in excess of sulphuric acid, and nearly insoluble in water; they are decomposable by similar means, as well as the native carbonates: they are both crystallizable from their hot aqueous solutions, and both attract carbonic acid. The carbonates are each soluble with effervescence in most of the acids; but the native carbonates are not so easily acted on as the artificial. Pure ammonia precipitates neither one nor the other.

The following are essential distinctions. Baryta and all its salts, except the sulphate, are poisonous. The corresponding strontitic salts are innocent. Baryta tinges flame yellow; strontia, red. Strontia has less attraction for acids than baryta; hence the strontitic salts are decomposed by baryta. The greater number of the barytic salts are less soluble than those of strontia, and they differ in their respective forms and solubilities. Pure baryta is ten times more soluble in water than pure strontia.

SECTION VII. *Magnesium.*

670. THE metallic base of magnesia has not hitherto been obtained; but, when that earth is negatively electrized with mercury, the resulting compoun decomposes water, and gives rise to the formation of *magnesia.* From the properties of the amalgam it appears that it is a white solid metal heavier than water, and highly attractive of oxygen.

671. *Magnesia or Oxide of Magnesium* is concluded, from indirect experiments, to consist of 11 metal + 7.5 oxygen; its representative number, therefore, is 18.5. It may be procured by exposing the carbonate of magnesia to a red heat. Magnesia is a white insipid substance, which slightly greens the blue of violets. Its specific gravity is 2.3; it is almost infusible and insoluble in water. I once succeeded in agglutinating a small portion of this earth in the voltaic flame, and whilst exposed to this high temperature, it was perfectly fused by directing upon it the flame of oxygen and hydrogen. A mixture of magnesia and lime is scarcely more fusible than the pure earth. It does not absorb carbonic acid or moisture, as is the case with the other alcaline earths.

672. *Native Magnesia* is a very rare mineral, and has hitherto been found only at *Hoboken,* in New Jersey. Its colour is greenish white; its texture lamellar and soft. According to the analysis of Dr. Bruce, it consists of

70	magnesia
30	water
100	

673. *Chloride of Magnesium* may be obtained by passing chlorine over red-hot magnesia; oxygen is expelled, and a substance obtained which moisture converts into muriate of magnesia.

674. *Muriate of Magnesia* is very deliquescent, and difficultly crystallized. Its solution has a bitter saline taste. Exposed to heat and air, muriatic acid flies off, and the magnesia remains pure. It consists of

Magnesia...	18.5
Muriatic acid	34.5
	53

675. Muriate of Magnesia is found in a few saline springs, and also in the water of the ocean. By evaporating a pint of sea-water we obtain

Common Salt	180.5 grs.
Muriate of Magnesia	23
Sulphate of Magnesia.........	15.5
Sulphate of Lime	7.1
	226.1

MURRAY'S *Analysis of Sea-Water, Edinburgh Phil. Trans.*, Vol. viii. p. 205.

The average specific gravity of sea-water is 1.026 or 1.028. It freezes at about 28.5°, and does not appear materially to differ in composition in different latitudes, provided it be taken from a sufficient depth. Near the mouths of rivers, and in the vicinities of melting ice or snow, its composition will of course vary.

676. *Chlorate of Magnesia* is a bitter deliquescent salt.

677. *Hydriodate of Magnesia* is deliquescent, and loses hydriodic acid by exposure to heat.

Iodide of Magnesium has not been examined.

678. *Nitrate of Magnesia* crystallizes in rhomboidal prisms, deliquescent, and soluble in its weight of water. Its taste is cooling and bitter, and it is decomposed at a red heat. It contains

Magnesia	18.5
Nitric acid	50.5
	69

679. *Ammonio-Nitrate of Magnesia* may be obtained by evaporating a mixed solution of nitrate of ammonia and nitrate of magnesia; it forms prismatic crystals of a bitter acrid taste, soluble in about 11 parts of water at 60°, and less deliquescent than their component salts separately.—FOURCROY, *Annales de Chimie*, iv. 215.

680. *Sulphuret of Magnesia.*—Sulphur and magnesia do not appear to form a complete sulphuret, for when melted together the compound does not dissolve in water; and when heated, the sulphur burns off.

681. *Hyposulphite of Magnesia* may be formed by boiling flowers of sulphur in solution of sulphite of magnesia; it is bitter, very soluble, but not deliquescent. Being more soluble in hot than cold water, it readily crystallizes as its solution cools; heated, the sulphur escapes, but it is not very combustible.

682. *Sulphite of Magnesia* is prepared by passing

sulphurous acid through water containing diffused magnesia. It forms tetraëdral crystals soluble in 20 parts of water at 60°.

683. *Sulphate of Magnesia* is a commonly occurring compound of this earth, much used in medicine as an aperient. It is largely consumed in the preparation of carbonate of magnesia. It crystallizes in four-sided prisms with reversed dihedral summits; or four-sided pyramids. Its taste is bitter. It is soluble in its own weight of water at 60°. When exposed to a red heat, it loses its water of crystallization, amounting to about 50 *per cent.*, but is not decomposed. It consists of

Magnesia....	18.5
Sulphuric acid	37.5
	56

In its crystallized state, it may be considered as composed of 1 proportional of dry sulphate + 7 proportionals of water, or 56 sulphate
59.5 water
115.5

684. This salt is usually obtained from sea-water, the residue of which, after the separation of common salt, is known by the name of *bittern*, and contains sulphate and muriate of magnesia; the latter is decomposed by sulphuric acid: a portion of muriate of magnesia often remains in the sulphate and renders it deliquescent: it is also occasionally obtained from saline springs; and sometimes by the action of sulphuric acid on magnesian limestone. It was once procured from the springs of Epsom in Surrey, and hence called *Epsom salt.* It has been found native, constituting the *bitter salt* and *hair salt* of mineralogists:

it not unfrequently occurs as a fine capillary incrustation upon the damp walls of cellars and new buildings.

685. The sulphate of magnesia of commerce is occasionally adulterated with small crystals of sulphate of soda; the fraud is detected by the inferior weight of the precipitate, occasioned by adding carbonate of potassa; 100 parts of pure crystallized sulphate of magnesia furnishing a precipitate of about 40 parts of dry carbonate.

686. *Ammonio-Sulphate of Magnesia* may be obtained by mixing solution of sulphate of ammonia with solution of sulphate of magnesia; or by pouring ammonia into a solution of the sulphate of magnesia, in which case, part only of the magnesia is thrown down, the remainder forming with the sulphate of ammonia this triple salt. It crystallizes in octoëdra and consists of

68	sulphate of magnesia
32	sulphate of ammonia
100	

FOURCROY, *Annales de Chimie*, vi.

687. *Sulphate of Potassa and Magnesia* forms rhomboidal crystals, scarcely more soluble than sulphate of potassa, and of a bitter taste.

688. *Phosphuret of Magnesia*, not examined.

689. *Hypophosphite of Magnesia*, not examined.

690. *Phosphite of Magnesia*, not examined.

691. *Phosphate of Magnesia* is formed by adding the carbonate of magnesia to phosphoric acid. It is insoluble? According to Fourcroy, crystals of phosphate of magnesia may be obtained by mixing the aqueous solutions of phosphate of soda and sulphate of mag-

nesia. The *bi-phosphate* crystallizes in irregular six-sided prisms, soluble in 14 parts of water at 60°, and efflorescent.

692. *Ammonio-Phosphate of Magnesia* is formed by mixing the solutions of phosphate of ammonia, and phosphate of magnesia; it precipitates in the form of a white crystalline powder, or in small four-sided prisms, tasteless, and scarcely soluble in water, but readily soluble in dilute muriatic acid. Exposed to a high temperature it falls into powder, evolves ammonia, and fuses with difficulty. According to Fourcroy, it contains equal weights of phosphate of ammonia, phosphate of magnesia, and water.

To separate magnesia from other earths, Dr. Wollaston availed himself of the formation of this triple phosphate. A mixture, for instance, of lime and magnesia may be dissolved in muriatic acid; and, upon the addition of bi-carbonate of ammonia, the lime is thrown down in the state of carbonate, but the magnesia is retained by the excess of carbonic acid. Filter and add a saturated solution of phosphate of soda, and in a short time the ammonio-magnesian phosphate falls down, 100 grains of which are equivalent to about 20 of magnesia. In occasionally employing this process, however, I have never been able to throw down the whole of the magnesia, a portion being under all circumstances retained in solution.

693. *Carbonate of Magnesia* is generally procured by adding carbonated alcalis to a solution of sulphate of magnesia. It is a white, insipid, and insoluble powder, which loses its acid at a red heat, and thus affords pure (calcined) magnesia. It contains

18.5 magnesia
20.7 carbonic acid
39.2

694. Carbonate of magnesia was first used in medicine early in the last century. It is often obtained from sea-water, after the separation of its common salt. It has been found *native* in Piedmont and Moravia, constituting the mineral called *magnesite.* It has also been found at Hoboken in veins in a serpentine rock, accompanying the native hydrate (672). It is generally white and friable, and in some places in fine acicular crystals.

695. *Bi-carbonate of Magnesia.*—Carbonate of magnesia is soluble in excess of carbonic acid, and this solution affords efflorescent crystals of *bi-carbonate* containing

18.5 magnesia
41.4 carbonic acid
59.9

This solution of magnesia, in excess of carbonic acid, is very useful in some calculous complaints.

696. *Borate of Magnesia* may be formed artificially. It occurs native in a mineral called *boracite,* hitherto only found in the duchy of Luneburgh. Its primitive form is the cube, but the edges and angles are generally replaced by secondary planes, and four of the angles are always observed to present a greater number of facets than the other four: these crystals become electric by heat; the most complex angles being rendered positive, and the simplest negative. It sometimes contains lime.

697. The salts of magnesia are for the greater part soluble in water, and afford precipitates of mag-

nesia, and of carbonate of magnesia, upon the addition of pure soda, and of carbonate of soda. Phosphate of soda occasions no immediate precipitate when added to a magnesian salt, but the addition of ammonia causes a white precipitate of the triple ammonio-magnesian phosphate.

698. The fossils which contain magnesia are generally soft and apparently unctuous to the touch; they have seldom either lustre or transparency, and are generally more or less of a green colour. *Steatite* or *soapstone, talc,* and *asbestos* may be taken as instances. The *chrysolite* also contains more than half its weight of magnesia. The mineral called *bitter spar,* of which the finest specimens come from the Tyrol, contains 45 *per cent.* carbonate of magnesia, 52 carbonate of lime, and a little iron and manganese. Its primitive crystal is a rhomboid nearly allied to that of carbonate of lime; its angles being 106° 20′, and 73° 80′. It is of a yellowish colour, and a pearly lustre; semi-transparent and brittle. A variety found at *Miemo* in Tuscany, has been called *Miemite.* The species of marble, termed *Dolomite,* found in the Alps, and in Icolmkill in Scotland, contains also a large quantity, generally 40 *per cent.* of carbonate of magnesia. The same may be said of the magnesian limestone of Derby and Nottingham: it is generally of a yellowish colour, and less rapidly soluble in dilute muriatic acid, than the purer limestones, whence the French have termed it *chaux carbonatée lente.* The lime which it affords is much esteemed for cements, but for agricultural purposes it is often mischievous, in consequence of its remaining caustic for a very long time, and thus injuring the young plant.

699. The separation of magnesia and lime is a problem of some importance in analytical chemistry, as they often exist together in the same mineral, more especially in the varieties of magnesian limestone. When solution of carbonate of ammonia is added to the mixed solution of lime and magnesia in nitric or muriatic acids, carbonate of lime falls, and the magnesia is retained in solution and may be separated by boiling: this method, however simple, is not susceptible of great accuracy, for a portion of carbonate of lime will always be retained along with the magnesia in solution, and a triple ammoniaco-magnesian salt is also formed. Mr. R. Phillips (*Quarterly Journal*, vi. 317) proposes the following process: "To the muriatic or nitric solution of lime and magnesia, add sulphate of ammonia in sufficient quantity; evaporate the mixture gradually to dryness, and then heat it to redness till it ceases to lose weight, by the volatilization of the muriate or nitrate of ammonia formed: note the weight of the mixed salt, reduce it to powder and wash it with a saturated solution of sulphate of lime till all the sulphate of magnesia appears to be dissolved; dry the sulphate of lime left, and by deducting its weight from that of the mixed sulphates the quantity of sulphate of magnesia dissolved will appear." After repeated trials of the various modes of separating lime and magnesia, I am induced to consider the following as least defective. To the mixed solution of lime and magnesia add oxalate of ammonia slightly acid, collect the precipitate, wash and dry it. 62 parts indicate 26.5 of lime. If nitric or muriatic acid were used for solution, the magnesia may afterwards be obtained by evaporation and heating the

residue to redness in a platinum crucible till it ceases to lose weight. If sulphuric acid were the solvent, the same operation affords dry sulphate of magnesia, of which 56 parts are equivalent to 18.5 magnesia.

SECTION VIII. *Manganese.*

700. THE common ore of manganese is the black or peroxide, which is found native in great abundance. The metal may be procured by exposing the protoxide mixed with charcoal, to an intense heat. It is of a bluish white colour, very brittle, and difficult of fusion. When exposed to air, it becomes an oxide. Its specific gravity is 8.

701. *Manganese and Oxygen.*—There are three definite oxides of manganese. The *protoxide* may be obtained by digesting the native black oxide in muriatic acid. Chlorine is abundantly evolved, and the hydrogen of the muriatic acid unites with part of the oxygen of the oxide to produce water. The metal thus partly deoxidized, is dissolved by the remaining muriatic acid, forming a *muriate of manganese.* Iron is almost always present, which, as Mr. Hatchett has shown, may be easily separated by neutralizing the muriatic solution with ammonia. The oxide of iron is directly precipitated, but oxide of manganese remains in solution and may be separated by *excess* of ammonia*. The

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* On the separation of iron from manganese, see *Quarterly Journal of Science and the Arts*, Vol. vi. p. 153.

solutions of protoxide of manganese furnish a white precipitate with the alcalis, which is a *hydrated oxide of manganese,* and which, when dried in close vessels, acquires an olive colour, and is the *protoxide.* Exposed to moist air, it passes into the state of deutoxide and peroxide.

702. When peroxide of manganese is heated red-hot till it ceases to give out gas, a dark reddish-brown *deutoxide* of manganese remains, which, when acted upon by sulphuric acid, is, according to Gay-Lussac, resolved into protoxide and peroxide. Exposed to moist air it absorbs oxygen, and is partly re-converted into peroxide. The deutoxide is most easily obtained pure, by triturating peroxide of manganese in fine powder with superoxalate of potassa and water: a pink solution is obtained, from which ammonia throws down the deutoxide.

703. The *Peroxide of Manganese* is black; it is not soluble in acids; and abounds as a natural product.

Native Peroxide of Manganese is found in Devonshire, Somersetshire, and Aberdeenshire, and occurs compact, and crystallized. The crystallized varieties have a grey metallic lustre, and are found acicularly radiated, and in rhomboidal prisms. It is generally blended with sulphate of baryta.

704. It appears probable that these are the only definite oxides of manganese. Their composition is variously stated by various chemists; according to the analyses of Berzelius (*Annales de Chimie,* lxxxvii.) they are composed as follows:

	Protoxide.	Deutoxide.	Peroxide.
Manganese	100.	100.	100.
Oxygen	28.1	42.16	56.2

From which it appears that the proportion of oxygen to that of metal is as 1., 1.5, and 2; and 28.1 : 100 :: 7.5 : 26.9, as the representative number of manganese. Dr. Davy's analysis of the chloride of manganese (707) which was made in an unexceptionable way, gives the number 28.5. As further experimental evidence is wanting, we shall not be far from the truth in assuming 28.5 as the equivalent of manganese, and the three oxides will then consist of

	Protoxide.		Deutoxide.		Peroxide.
Manganese, 1 prop^l.	28.5		28.5		28.5
Oxygen.... 1	7.5	1.5 prop^l.	11.25	2 prop^l.	15.
	36		39.75		43.5

705. When equal parts of black oxide of manganese and nitre are ignited, a compound results which has been called *cameleon mineral,* in consequence of the changes of colour which its aqueous solution exhibits. M. M. Chevillot and Edwards have ascertained, that in this compound the black oxide of manganese has absorbed an additional proportion of oxygen, and acquired the property of forming a neutral *manganesate of potassa,* which exists in the red cameleon, and may be obtained in crystals. When there is excess of alcali, the cameleon is green.—*Annales de Chimie et Physique,* Tom. iv.

706. *Manganese and Chlorine.*—By burning the metal in chlorine, or by exposing muriate of manganese to a strong heat, a pink semitransparent flaky substance is obtained, which, when dissolved in water, produces a muriate of manganese.

707. *Muriate of Manganese* may also easily be formed by heating excess of the black oxide with muriate of ammonia in a crucible, dissolving the mass in water and

filtering. If this solution be evaporated to dryness and fused out of the contact of air, the crystallized chloride is obtained. Heated in contact of air, it is decomposed, and oxide of manganese remains. In this decomposition it is a question whether the chlorine is expelled by the superior attraction of the oxygen for manganese; or whether the moisture in the air, or in the compound itself is concerned in the change. This chloride consists, according to Dr. Davy (*Phil. Trans.* 1812, p. 184) of

54	chlorine
46	manganese
100	

So that it may be regarded as a compound of

1	proportional manganese	28.5
1	———— chlorine	33.5
		62

708. *Chlorate of Manganese* has not been examined, nor has the action of iodine or of its acids upon this metal been investigated.

709. *Nitrate of Manganese.*—Dilute nitric acid readily dissolves protoxide of manganese, and forms a very soluble and difficultly crystallizable *proto-nitrate.* The same salt may be obtained by digesting peroxide of manganese in nitric acid with a portion of gum or sugar, which abstracts oxygen, carbonic acid is evolved, and the protoxide dissolved by the acid. Exposed to light, the solution of the protonitrate lets fall a portion of peroxide of manganese.

When dilute nitric acid is poured upon the deutoxide of manganese, a protonitrate and peroxide are formed.

The composition (theoretical) of nitrate of manganese is

36 protoxide
50.5 acid
86.5

710. *Manganese and Sulphur* appear unsusceptible of combination; but a compound of oxide of manganese and sulphur is found in Transylvania and Cornwall. It is of a blackish grey colour and metallic lustre. The black oxide of manganese heated with sulphur forms a greenish compound, and abundance of sulphurous acid is evolved: is this a sulphuret, or a sulphuretted oxide of manganese?

711. *Hyposulphite of Manganese* remains in solution when sulphate of manganese is decomposed by hyposulphite of lime.

712. *Sulphate of Manganese* is formed by dissolving the protoxide or protocarbonate in the acid, and evaporating to dryness: a white *protosulphate* is formed, which crystallizes in rhomboidal prisms, and consists of

36 protoxide
37.5 sulphuric acid

It is very soluble in water, and has a bitter styptic taste: at a bright red heat it gives out oxygen, and sulphurous acid and deutoxide of manganese remain. It may also be obtained by mixing peroxide of manganese into a paste with sulphuric acid, and heating it in a basin nearly to redness: oxygen is evolved, and the dry mass washed with water affords the sulphate.

713. *Deutosulphate of Manganese* is formed by

digesting the deutoxide in sulphuric acid diluted with its bulk of water: a red solution is formed, but the salt cannot be obtained in a neutral or separate state, for the application of heat evolves oxygen, and forms protosulphate. It is, probably, to a little deutosulphate that the occasional red tinge of the protosulphate is to be attributed.

714. *Phosphuret of Manganese* is of a blue white metallic lustre, and considerably inflammable.

715. *Phosphite* and *Hypophosphite of Manganese* have not been examined.

716. *Phosphate of Manganese* is precipitated in the form of a white insoluble powder, by adding phosphate of soda to muriate of manganese.

717. *Carbonate of Manganese* is white, insipid, and insoluble in water. It is precipitated by alcaline carbonates from the protomuriate or protosulphate, and consists of

36	protoxide
20.7	carbonic acid

718. The salts of manganese containing the protoxide are mostly soluble in water, and the solution becomes turbid and brown by exposure to air. They are not precipitated by hydriodic acid; they furnish white precipitates with the alcalis, which soon become discoloured by exposure to air; they are precipitated white by ferro-prussiate of potassa, and yellow by hydrosulphuret of ammonia.

719. The native peroxide of manganese is used in the laboratory as a source of oxygen, and is largely employed in the preparation of chlorine, especially by the bleachers. It is used in glass-making, and, when

added in excess, gives it a red or violet colour. It is also employed in porcelain painting; and it gives common earthen-ware a black colour, by being mixed with the materials before they are formed into vessels.

SECTION IX. *Iron.*

720. THE most important native combinations of iron, whence the immense supplies for the arts of life are drawn, are the oxides. Iron is also found combined with sulphur, and with several acids; it is so abundant that there are few fossils free from it. It is also found in some animal and vegetable bodies; and in several mineral waters.

Iron is a metal of a blue white colour, fusible at a white heat. Its specific gravity is 7.77. It has not been so long known as many of the other metals; it was, however, employed in the time of Moses for cutting instruments. It is extremely ductile, but cannot be hammered out into very thin leaves.

721. Iron is sometimes found native, and is usually regarded as of meteoric origin, for it is invariably alloyed by a portion of the metal nickel, and a similar alloy is found in *meteoric stones*. *Native Iron* is flexible, cellular, and often contains a green substance of a vitreous appearance. It has been found in Africa, in America, and in Siberia, where a mass of it weighing 1600 lbs. was discovered by Professor Pallas. The mass found

in Peru, described by Don Rubin de Celis, weighed 15 tons. In the year 1751, a mass of the same substance was seen to fall from the atmosphere in Croatia. It appeared as a large globe of fire, and is preserved in the imperial museum of Vienna.

722. *Iron and Oxygen.*—Exposed to heat and air, iron quickly oxidizes. It unites with oxygen in at least two proportions. The *protoxide* may be procured by precipitating a solution of sulphate of iron by potassa, washing the precipitate out of the contact of air, and drying it at a red heat. It is black, and consists of 26 iron + 7.5 oxygen = 33.5. It is supposed by M. Gay-Lussac, that in drying, an additional proportion of oxygen is always absorbed, and that the black oxide is a deutoxide composed of 100 metal + 37.8 oxygen; (*Ann. de Chim. et Phys.*, Tom. i.) but there is some reason to doubt the accuracy of this conclusion.

The recently precipitated protoxide of iron is sparingly soluble in ammonia, and in carbonated alcalis.

Black protoxide of iron may also be obtained by burning iron in oxygen gas: this very beautiful experiment was devised by Dr. Ingenhous, and is best performed by attaching a straight piece of watch spring, wound round with harpsichord wire, to the stopper of an air-jar of oxygen gas: the end of a brimstone match may be attached to the wire, and inflamed at the time of plunging it into the gas; it heats the wire red hot, which then burns and drops in black globules of oxide into the water beneath.

This oxide of iron used to be prepared for pharmaceutical use, by moistening iron filings with a small quantity of water, and exposing them to the air for a day or two; a quantity of black oxide thus forms, which is separated by washing, and the process repeated till the whole of the metal is thus oxidized. It was called *martial ethiops.* It is black, tasteless, and insoluble in water.

723. When protoxide of iron is boiled in nitric acid, and precipitated by ammonia, washed, and dried at a low red heat, it increases in weight, and acquires a brown colour. This is the *peroxide,* composed of 26 iron + 11.75 oxygen = 37.75. It has sometimes been called *Saffron of Mars.*

724. The number 26, as the equivalent of iron, is founded on the presumption that it exists as a protoxide in the sulphate: now 100 grains of pure iron, during solution in sulphuric acid, evolve 170 cubic inches of hydrogen at mean temperature and pressure, and consequently 85 cubic inches of oxygen = 28.68 grs. have been transferred to the iron: and 28.68 : 100 :: 7.5 : 26.1. The quantity of oxygen in the peroxide of iron is shown to be to that in the protoxide as 3 to 2 by the following experiment. 100 grains of iron were dissolved in nitric acid, and the solution evaporated to dryness, and the residue sufficiently heated to drive off the whole of the acid: 143 grains of peroxide remained. So that the composition of these oxides stands thus:

	Protoxide.		Peroxide.
Iron...	100	....	100
Oxygen	28.68	....	43
	128.68		143

And 28.68 . 43 :: 7.5 : 11.25 = 1½ proportional of oxygen.

M. Gay-Lussac (*Ann. de Chim. et Phys.* i., and *Ann. de Chim.* lxxx.) has detailed some experiments, which he considers as demonstrating the existence of a third definite oxide of iron, intermediate between the above oxides, and composed of iron 100 + oxygen 37.8. Such a compound he thinks is obtained by passing steam for a length of time over red-hot iron: it seems, however, very questionable whether this be a definite compound: it is rejected by Berzelius, who only admits the oxides above described.

M. Thenard, in describing the oxides of iron, (*Traité* ii. 75. *Edit.* 2.) considers the octoëdral and magnetic iron ores as composed of this deutoxide, and does not allow of the existence of native protoxide of iron. In the present state of the question, however, I should feel rather inclined to view this deutoxide as a mixture of the protoxide and peroxide, than as any definite compound, more especially as the analyses of the native magnetic oxides give variable proportions of oxygen.

In order that the representative number of iron may also be its equivalent number, it is represented by 26. But the peroxide, instead of consisting of 1 proportional metal + 2 oxygen, consists of 1 proportional metal + 1.5 oxygen; and the chloride and perchloride bear the same relation to each other. The case however is different with the sulphurets; for the sulphuret consists of 1 proportional iron + 1 sulphur: and the bi-sulphuret of 1 iron + 2 sulphur.

M. Gay-Lussac has shown the curious fact, that although red-hot iron decomposes water, hydrogen is capable of decomposing all the oxides of iron at a red heat.—*Ann. de Chim. et Phys.*, i. 37.

725. The *Native Oxides of Iron* constitute a very extensive and important class of metallic ores. They vary in colour, depending upon mere texture in some cases; in others, upon the degree of oxydizement. Some varieties are magnetic, and those which contain least oxygen are attracted by the magnet.

Magnetic Iron Ore is generally black, with a slight metallic lustre. It occurs massive and octoëdral. It is often sufficiently magnetic to take up a needle. Its specific gravity is 4.5. It occurs chiefly in primitive countries, and is very abundant at Roslagen in Sweden, where it is manufactured into a bar-iron particularly esteemed for making steel.

Another variety of oxide of iron is called *iron glance*, and *micaceous iron ore*. It is found crystallized of singular beauty, in the isle of Elba; and occasionally among the volcanic products of Vesuvius and the Lipari Islands.

A third variety is *Hæmatite*, or red iron-stone; it occurs in globular and stalactitic masses, having a fibrous and diverging structure. In this country it abounds near Ulverstone in Lancashire; and most of our iron-plate, and wire, is made from it. Sometimes it is of a brown, black, or ochraceous colour.

A fourth variety of oxide of iron, is known under the term of *clay-iron-stone*, on account of the quantity of argillaceous earth with which it is contaminated. It is found in masses of different shapes and sizes, and sometimes in small rounded nodules like peas. Some of the globular masses are called *ætites*. It is abundant in the coal formations of Shropshire, South Wales, Staffordshire, and Scotland.

Though this is far from the purest iron ore found in this country, it is the chief source of the cast and bar iron, in ordinary use. Its employment is chiefly referable to the coal which accompanies it.

The essential part of the process by which these ores of iron are reduced, consists in decomposing them by the action of charcoal at high temperatures. The argillaceous iron of Wales, Shropshire, *&c.*, is first roasted, and then smelted with lime-stone and coke; the use of the former being to produce a fusible compound with the clay of the ore, by which the latter is enabled to act upon the oxide, and to reduce it to the metallic state.

726. The two oxides of iron form distinct salts with the acids.

The salts containing the black oxide are of a green colour, mostly crystallizable, become reddish brown by exposure to air, and their solutions absorb nitric oxide gas and become of a deep olive colour.

The salts with the brown oxide do not, with very few exceptions, crystallize; they are brown, soluble in alcohol, and do not absorb nitric oxide.

The alcalis precipitate hydrated oxides from these solutions.

727. *Iron and Chlorine* unite in two proportions; the *chloride* may be obtained by evaporating *protomuriate of iron* to dryness, and exposing the residuum to a red heat, out of the contact of air. A grey brittle lamellar substance is formed, consisting of one proportional of iron and one of chlorine; 26 + 33.5.

That the chlorine in the protochloride of iron is to that in the perchloride as 1 to 1.5, is shown by Dr.

Davy in his valuable paper on the chlorides, (*Phil. Trans.*, 1812, 169.) and the equivalent number of iron, as deduced from his analysis, is somewhat above that here adopted. It must be confessed that the anomaly in the oxides and chlorides of iron throws some difficulty in the way of applying to them their equivalent numbers, but as the foundations of chemistry are purely experimental, we must not endeavour to do away that difficulty by a theoretical substitute. There is a difference in the relations of iron to oxygen and chlorine, compared with its relation to sulphur, which does not exist elsewhere; of the cause of this difference we are at present ignorant.

728. When iron wire is heated in chlorine, it burns with a red light, and produces a compound which rises in beautiful brown scales. It is the *perchloride of iron,* and consists of one proportional of iron, and one and a half of chlorine; 26 + 50.25. The chloride and perchloride of iron produce *protomuriate* and *permuriate* of iron when acted upon by water.

729. *Chlorate of Iron* has not been examined.

730. *Muriate of Iron.*—When iron filings are dissolved in muriatic acid, a greenish brown solution results, which contains a mixture of the protomuriate and permuriate.

731. *Protomuriate of Iron* is best obtained by digesting black sulphuret of iron in dilute muriatic acid; sulphuretted hydrogen is evolved, and a green solution obtained, which, filtered and evaporated, yields pale green crystals, very soluble, and of a styptic taste. This salt abundantly absorbs nitric oxide gas; the solution is of a very deep brown colour; when heated,

red oxide of iron falls and a portion of ammonia is formed; a great part of the gas at the same time escapes.

This salt may also be obtained by dissolving iron filings in muriatic acid excluded from air; but the above process is preferable, as the sulphuretted hydrogen prevents any part of the iron passing into the state of permuriate.

732. *Permuriate of Iron* is formed by digesting the peroxide in muriatic acid: it dissolves without the evolution of chlorine, and when evaporated to dryness, furnishes a reddish brown deliquescent mass of a very astringent taste, soluble both in water and alcohol. It forms the basis of the *tinctura ferri muriatis* of the London *Pharmacopœia.* Permuriate of iron is also formed by exposing the protomuriate to air; and by acting upon it by nitric acid. Exposed to heat, muriatic acid, chlorine, and water are evolved, chloride of iron sublimes, and a portion of peroxide remains in the retort.

733. When muriate of ammonia and peroxide of iron are mixed and exposed to heat in a proper subliming vessel, a yellow sublimate is obtained, which is the *ens veneris* and *flores martiales* of old pharmacy: the *ferrum ammoniatum* of the present *Pharmacopœia;* it consists chiefly of muriate of ammonia, with a small but variable proportion of permuriate of iron.

734. *Iodine and Iron* readily form a brown compound, fusible at a red heat, and which, when acted upon by water, forms a *hydriodate* of a green colour.

735. *Iodate of Iron* has not been examined.

736. The *nitric acid* dissolves the protoxide and peroxide of iron, and produces a green *protonitrate* and a red *pernitrate.*

Nitric acid, diluted with a very little water, acts violently on iron and peroxidizes it, a vast quantity of gas being at the same time generated, which consists of a mixture of nitrous and nitric oxides; and a solution is formed of a reddish brown colour containing *pernitrate* of iron, and affording a brown precipitate to the alcalis.

If the nitric acid be considerably diluted, (sp. gr. 1.16) the action is slow and very little gas escapes; the solution acquires an olive brown colour from the nitric oxide which it contains, but exposed to the air it becomes pale green in consequence of the escape of that gas. The alcalis produce a green precipitate in this solution: it cannot be obtained in crystals by the usual process, and passes into pernitrate by exposure to air.

737. *Sulphur and Iron.*—There are two sulphurets of iron: the *black sulphuret* is composed of 26 iron + 15 sulphur; and the *yellow sulphuret*, or *bi-sulphuret*, of 26 iron + 30 sulphur. The former compound is produced by melting sulphur with iron filings; it exists in nature under the name of *magnetic pyrites:* the bisulphuret is exclusively a natural product, very abundant, and called *iron pyrites.*

Magnetic pyrites is not found crystallized; it is generally brown, or whitish yellow, and is not a common mineral.

Common pyrites is found massive, and crystallized in a variety of forms; its primitive form is the cube. It often occurs in nodules. Its colour is different shades of brass yellow.

That the magnetic pyrites contains just half the proportion of sulphur existing in the common pyrites was first shown by Mr. Hatchett. (*Phil. Trans.*, 1804).

The principal use of pyrites is in the formation of *green vitriol*, for which purpose the ore is gently roasted and exposed to air and moisture. Some varieties are spontaneously decomposed, and furnish this salt. Pyrites has also lately been used in the production of sulphuric acid (325).

738. *Sulphates of Iron.*—The sulphuric acid with the protoxide of iron forms a *protosulphate of iron*, which crystallizes in green rhomboidal prisms, of a styptic taste, soluble in twice their weight of cold water, and insoluble in alcohol. This salt is called *copperas* or *green vitriol*, and is often prepared by exposing roasted pyrites to moisture, in which case it is impure. It is usually formed by dissolving iron filings, or turnings, in dilute sulphuric acid, filtering and evaporating the solution, and setting it aside to crystallize. It is also obtained, perfectly free from persulphate, by acting upon sulphuret of iron by dilute sulphuric acid. It consists of one proportional of protoxide $= 33.5 +$ 1 proportional of acid $= 37.5$, and in its crystallized state contains seven proportionals of water $= 59.5$. Its solution absorbs nitric oxide gas, and acquires a deep brown colour; it also absorbs chlorine, muriatic acid is formed, and the iron becomes peroxidized, so that water is here decomposed.

Exposed to air and moisture, the protosulphate of iron gradually absorbs oxygen, and is partly converted into a persulphate. It may also be converted into persulphate by nitric acid. When heated, it fuses in its water of crystallization, and at a high temperature evolves a mixture of sulphurous and sulphuric acids, peroxide of iron remaining in the vessel: by this process sulphuric acid used formerly to be prepared, and the residue was known under the name of *caput mortuum vitrioli* or *colcothar*. If the green crystals of this salt be exposed to a temperature of about 300°, they lose a portion of water, and crumble down into a white powder.

739. *Native Green Vitriol* is frequently found associated with iron pyrites, being produced by its decomposition: it occurs in several of our coal mines.

740. *Persulphate of Iron* is obtained by dissolving the moist red oxide in dilute sulphuric acid; it does not crystallize, but affords, by evaporation, a brown deliquescent mass, consisting of 1 proportional of peroxide + 1.5 sulphuric acid, or 37.75 oxide + 56.25 sulphuric acid. It is formed in the mother waters of the sulphate. Its taste is highly astringent, and when dry it becomes white: if in this state it be digested in hot sulphuric acid, or if peroxide of iron, recently precipitated from the pernitrate, be boiled with excess of sulphuric acid, the solution yields octoëdral crystals nearly white, and of a sweetish styptic taste: these are probably a *bi-persulphate of iron.*

741. *Phosphuret of Iron* may be formed by dropping phosphorus into a crucible containing red-hot iron wire; it is a brittle grey compound, and acts upon the magnet. Upon the subject of the magnetic qualities of the sulphuret and phosphuret of iron, the reader is referred to Mr. Hatchett's analysis of the magnetical pyrites. (*Phil. Trans.*, 1804).

742. *Phosphates of Iron.*—These are both insoluble, and may be formed by adding solution of phosphate

of soda, to protosulphate and persulphate of iron. The *protophosphate* of iron is of a pale blue colour; the *perphosphate* is white.

743. *Native Protophosphate of Iron* occurs in the form of a blue earthy powder, and also in prismatic crystals. The former has sometimes improperly been termed *Native Prussian Blue,* and has been found in alluvial soil: the latter occurs with iron pyrites in Cornwall.

744. *Iron and Carbon.*—The different kinds of cast iron and of steel contain more or less carbon, which materially affects their properties. The substance termed *Plumbago, Graphite,* or *Black Lead,* is generally regarded as a true *carburet of iron:* this is not an uncommon mineral, though rarely found of sufficient purity for the manufacture of pencils: at Borrodale in Cumberland, where it occurs particularly pure, it is in imbedded masses in slate and grauwacke: the coarser kinds and the dust, are melted with sulphur for common carpenters' pencils: crucibles are sometimes made of it, and it forms an ingredient in compositions for covering cast-iron, and for diminishing friction in machines. According to Messrs. Allen and Pepys it consists of

95	carbon
5	iron
100	

It may here be observed, that considerable difficulty attends the accurate analysis of compounds of carbon and iron, in estimating the proportion of the former; this has generally been indirectly effected by ascertaining the quantity of iron, and considering the loss of weight as carbon, a method obviously objectionable.

If the action of dilute sulphuric acid be resorted to, a portion of carbon is carried off by hydrogen; the same is the case with muriatic acid; and if nitric acid be used, some carbonic acid may be formed, and artificial tannin is produced.

Plumbago is infusible, and burns with great difficulty: its composition was ascertained by the above-mentioned chemists, by exposing it in the apparatus used for burning the diamond, to a current of oxygen at a red heat, and ascertaining the quantity of carbonic acid and of oxide of iron thus produced.

745. *Carbonic Acid* may be combined with the protoxide of iron, by adding carbonate of potassa to sulphate of iron; a green precipitate of *protocarbonate of iron* falls, which, exposed to air, becomes brown, and evolves carbonic acid. Solution of bi-carbonate of potassa occasions a white precipitate with sulphate of iron, part of which is re-dissolved on adding excess of the carbonated alcali.

746. *Spathose Iron Ore*, is a native carbonate of iron, containing a little manganese and carbonate of lime. It occurs in Germany, and in some parts of Cornwall, crystallized in imperfect rhomboids. Its colour is yellowish, or brownish grey.

747. When hydrocyanate of potassa is added to the solutions of salts of iron, it occasions a bluish white precipitate in those containing the protoxide, and a blue precipitate in those containing the peroxide. The former precipitate is probably a ferrocyanate of iron, containing the protoxide; the latter, a ferrocyanate, containing the peroxide, and which has been long known under the name of *Prussian Blue.*

748. Prussian blue is usually prepared by the following process:—Equal parts of subcarbonate of potassa and some animal substance, such as dried blood, or horn shavings, are heated red hot, in a crucible, and six or eight parts of water are poured upon the mixture when it has quite cooled. The solution is filtered and found to contain *hydrocyanate of potassa*, along with carbonate of potassa, and some other products. It is mixed with a solution containing two parts of alum and one of sulphate of iron; a precipitate falls, at first of a dingy green hue, but which, by copious washings with very dilute muriatic acid, acquires a fine blue tint, and is called *Prussian Blue*, having been discovered by Diesbach, a colour-maker of Berlin, in 1710. The first description of the mode of preparing it is given by Woodward in the *Phil. Trans.* for 1724.

In this process the animal matter is decomposed, and resolved into a variety of products arising from the reunion of its ultimate component parts. The matter remaining in the crucible contains cyanuret of potassium; and when acted upon by water, hydrocyanate of potassa, with a little carbonic acid and ammonia, is formed in consequence of the decomposition of a portion of the water; and consequently the principal salts contained in the washings of the black matter remaining in the crucible are carbonate and hydrocyanate of potassa, which, when added to a solution of sulphate of iron, form a precipitate of oxide and ferrocyanate of iron; the former is removed by the dilute muriatic acid. The aluminous earth of the alum gives a *body* to the precipitate, which improves it as a pigment.

The above seems to be the simplest view of the formation and composition of Prussian blue; a variety of other opinions respecting its nature have been entertained, but they require further experimental verification.

749. Pure Prussian blue, obtained by adding ferrocyanate of potassa to solution of persulphate of iron, is a tasteless substance insoluble in water and alcohol. It is not acted upon by dilute nitric, sulphuric, or muriatic acids, which renders it extremely improbable that it should be a hydrocyanate of iron, and strengthens the opinion of Mr. Porrett, that it is a *ferrocyanate*, or a compound of peroxide of iron with the peculiar acid mentioned below (752), and containing hydrogen, oxygen, iron, and cyanogen.

750. When Prussian blue is boiled with potassa it is decomposed; it loses its blue colour, oxide of iron is separated, and on filtering and evaporating the solution, a triple salt is obtained, consisting of hydrocyanic acid, potassa, and oxide of iron; this has been called *triple prussiate of potassa*, and *ferrocyanate of potassa.* It is best formed by adding powdered Prussian blue, previously heated with a dilute sulphuric acid composed of one part of acid and five of water, and afterwards washed, to a hot solution of potassa, as long as its colour is destroyed. This salt forms permanent yellow cubic and tabular crystals, more soluble in hot than cold water, insoluble in alcohol, and of a peculiar taste. Boiled with dilute sulphuric or muriatic acids, hydrocyanic acid is given out, and a precipitate formed similar to that which the salt produces in a solution of protosulphate of iron. It is decomposed in a retort at a red

heat, hydrocyanic acid and ammonia are evolved, and the residue consists of charcoal, potassa, and iron.

Exposed to a red heat in a platinum crucible, a brown mass is obtained, which, washed with water, deposits a grey cyanuret of platinum. The aqueous solution furnishes, on evaporation, hydrocyanate of potassa and a large quantity of transparent colourless prismatic crystals.—Thenard, *Traité*, 2d edit., iii. 528.

751. The *ferrocyanates of ammonia, soda, lime, magnesia, baryta,* and *strontia,* may be obtained by boiling those alcalis and earths with Prussian blue.

752. Mr. Porrett (*Phil. Trans.*, 1814.) considers the ferrocyanates as compounds of the respective bases, with an acid consisting of the elements of the hydrocyanic acid united to the protoxide of iron. This acid he terms *ferrochyazic acid,* derived from the initial letters of carbon, hydrogen, and azote. He obtained this acid dissolved in water, by adding to a solution of ferrocyanate of baryta just sulphuric acid enough to precipitate the baryta. It has a pale yellow colour, no smell, and is decomposed by a gentle heat or strong light, in which case hydrocyanic acid is formed, and white hydrocyanate of iron is deposited, which becomes blue by exposure. Gay-Lussac, observing the production of the ferrocyanate of potassa by adding protoxide of iron to hydrocyanate of potassa, supposes that a portion of the hydrocyanic acid is decomposed by the oxide, giving rise to a compound of cyanuret of iron with hydrocyanate of potassa.

753. The following table shows the colours of the precipitates occasioned by solution of ferrocyanate of potassa, in different metallic solutions:

METAL.	SOLUTION.	PRECIPITATE.
MANGANESE . .	Neutral protomuriate	White
IRON	Neutral protosulphate	White or pale blue
Ditto	Permuriate	Prussian blue
ZINC	Muriate	Yellowish white
TIN	Acid protomuriate	White, then yellow and bluish
Ditto	Acid permuriate	Pale yellow
CADMIUM	Muriate	
COPPER	Protomuriate	Lilac
Ditto	Pernitrate	Deep brown
LEAD	Nitrate	White
ANTIMONY	Tartrate of antimony and potassa	0
BISMUTH	Tartrate of bismuth and potassa	0
COBALT	Muriate	Pale green
URANIUM	Sulphate	Deep brown
TITANIUM	Acid muriate	Deep blue (from acid)
Ditto	Neutral sulphate	Sap green
CERIUM		
TELLURIUM . . .		
ARSENIC	White oxide	
Ditto	Arsenic acid	
NICKEL	Sulphate	Grey
MERCURY	Acid nitrate	Greenish white
Ditto	Acid pernitrate	Ditto
Ditto	Corrosive sublimate	White
RHODIUM		
PALLADIUM . . .		
SILVER	Nitrate	Cream colour
GOLD	Muriate	0
PLATINUM	Nitrate	Yellow

All the above precipitates appear to be ferrocyanates, for when treated with solution of potassa, a ferrocyanate of potassa is obtained.

754. *Borate of Iron* is of a yellow colour and insoluble. It is formed by adding borate of soda to sulphate of iron.

755. The salts of iron are mostly soluble in water, and the solution is reddish brown, or becomes so by exposure to air. It affords a blue precipitate with ferrocyanate of potassa; and a black precipitate with hydrosulphuret of ammonia. Infusion of gall-nuts produces a black or deep purple precipitate. The hydriodic acid occasions no change.

756. Of the alloys of iron, *tin-plate* is the only one of consequence. It is made by dipping clean iron plates into melted tin. The process is described at length by Mr. Parkes. (*Quarterly Journal*, Vol. viii. 141.) When tin-plate is washed over with a weak acid, the crystalline texture of the tin becomes beautifully evident, forming an appearance which has been called *moiré metallique.—Quarterly Journal of Science*, Vol. v. p. 368.

757. An extremely important part of the chemical history of iron relates to the varieties of the metal which are found in commerce. These are much too numerous to be dwelt upon here; so that we shall limit our observations to the principal of them only, which are *cast iron, wrought iron*, and *steel*.

Of cast iron there are two principal varieties distinguished by the terms *white* and *grey*. The first is very hard and brittle, and, when broken, of a radiated texture. Acids act upon it but slowly, and exhibit a texture composed of a congeries of plates, aggregated in various positions.—DANIELL, *Quarterly Journal of Science and Arts*, Vol. ii. p. 280.

Grey or mottled iron is softer and less brittle; it may be bored, and turned in the lathe. When immersed in dilute muriatic acid, it affords a large quantity of black insoluble matter, which Mr. Daniell considers as a triple compound of carbon, iron, and silicium, and which has some very singular properties. The texture of the metal resembles bundles of minute needles.

Cast iron is in this country converted into wrought iron by a curious process, called *puddling*. The cast iron is put into a reverberatory furnace, and when in fusion is stirred, so that every part may be exposed to the air and flame. After a time the mass heaves, emits a blue flame, and gradually grows tough and becomes less fusible, and at length congeals. In that state it is passed successively between rollers, by which a large quantity of extraneous matter is squeezed out, and the bars are now malleable. They are cut into pieces, placed in parcels in a very hot reverberatory, and again hammered or rolled out into bars. They are thus rendered more tough, flexible, and malleable, but much less fusible, and may be considered as nearly pure iron.

Analysis shows that cast iron contains oxygen, carbon, often sulphur and phosphorus, either silica or silicium, and it appears very probable that calcium exists in some of the varieties.

By the processes of puddling and rolling, these substances are burned away or squeezed out, and thus malleability is conferred upon the metal by rendering it more pure. A specimen of cast iron analyzed by Berzelius afforded Iron 91.53—Manganese 4.57—Carbon 3.90.

A bar of wrought iron, when its texture is examined in the mode pointed out by Mr. Daniell, presents a fasciculated appearance, the fibres running in a parallel and unbroken course throughout its length. This structure may be well seen by tearing a bar of wrought iron asunder.

758. Steel is a compound of iron with carbon, the proportions being variable. It combines the fusibility of cast with the malleability of bar iron, and when heated and suddenly cooled it becomes very hard, whence its superiority for the manufacture of cutting instruments. If kept for a long time in fusion, it loses carbon and becomes pure iron.

Iron is converted into steel by a process called *cementation*, which consists in heating bars of the purest iron in contact with charcoal: it absorbs carbon and increases in weight, at the same time acquiring a *blistered* surface. This, when drawn down into smaller bars and beaten, forms *tilted steel*; and this broken up, heated, welded, and again drawn out into bars, forms *shear steel*. *English cast steel* is prepared by fusing blistered steel with a flux composed of carbonaceous and vitrifiable ingredients, casting it into ingots, and afterwards, by gentle heating and carefully hammering, giving it the form of bars.

759. Messrs. Stodart and Faraday found, that by intensely heating pure steel with charcoal powder, a *carburet of iron* of a dark grey colour, very brittle and highly crystalline, was formed, which afforded, upon analysis,

94.36	iron
5.64	carbon
100	

In this compound, which was frequently made and afforded the same results on analysis, and which therefore may be regarded as definite, the proportion of carbon very far exceeds that in steel, so that the latter is probably a compound of pure iron with a variable proportion of the true carburet.

760. The following table, drawn up by Mr. Mushet, shows the quantities of charcoal which disappeared during the conversion of iron into the different *subcarburets of iron* known in commerce.—*Phil. Mag.* xiii. :

Charcoal absorbed.	RESULTS.
$\frac{1}{120}$	soft cast steel
$\frac{1}{100}$	common cast steel
$\frac{1}{90}$	the same, but harder
$\frac{1}{50}$	the same : too hard for drawing
$\frac{1}{25}$	white cast iron
$\frac{1}{20}$	mottled cast iron
$\frac{1}{50}$	black cast iron

When the carbon amounts to $\frac{1}{60}$ of the whole mass, the hardness is at a maximum.

761. *Wootz* or *Indian steel* is truly valuable for the purpose of making edge tools. Its peculiar excellence is owing to combination with a minute portion of the earths alumina and silica ; or rather, perhaps, with the bases of these earths. (*Quarterly Journal of Science*, vii., 288.) Whether the earths are found in the ore, or are furnished by the crucible used in making the steel, is not certainly known ; nor is the Indian steel-maker probably aware of their presence. Wootz, in the state in which it is imported, is not fit to make into fine cutlery. It requires a second fusion, by which the

whole mass is purified and equalized, and fitted for forming the finest edge instruments.

762. The texture of steel, as exhibited by the action of an acid, is not fibrous, but appears somewhat lamellated.

763. When steel is heated to a cherry-red colour, and then plunged into cold water, it becomes so extremely hard and brittle, as to be unfit for almost any practical purpose. To reduce it from this extreme hardness, is called by the workmen *tempering*, and is effected by again heating the steel to a certain point. The surface being a little brightened, exhibits, when heated, various colours which constantly change as the temperature is increased, and by these colours it has been customary to judge of the temper of the steel.

A more accurate as well as convenient method is to use a bath and thermometer; the bath may be of mercury, or of the fusible mixture of lead, tin, and bismuth, or, indeed, of any fluid whose boiling point is not much under 600°. Into this bath the articles to be tempered are put, together with the bulb of a thermometer graduated to near the boiling point of mercury. The corresponding degrees at which the various colours appear are from 430° to 600°. The first change is at about 430°, but this is too faint to be distinguished, except by comparison with another piece of untempered polished steel. At 460° the colour is straw, becoming deeper as the temperature is increased; at 500° the colour is brown; this is followed by a red tinge with streaks of purple, then purple, and at nearly 600° it is blue.

The degrees at which the respective colours are produced being thus known, it follows that the workman has only to heat the bath, with its contents, up to the required point. For example, suppose the blade of a penknife (or one hundred of them) to require tempering: they are suffered to remain in the bath until the mercury in the thermometer rises to 460°, and no longer, that being the heat at which the knife (supposing it to be made of the best English cast steel) will be sufficiently tempered.

The advantages attending this method are obvious: the heat is equally applied to the whole; and the workman, instead of attending to the colour of each blade, has only to observe the thermometer.

Some recent experiments, proving that steel, for certain uses, is sufficiently tempered long before it is heated to produce any change of colour, promise to give additional value to this process by a thermometer. The knife edges attached to the pendulum described by Capt. Kater, *Phil. Trans.*, 1818, p. 38.) were forged by Mr. Stodart, from a piece of fine wootz. They were carefully hardened, and tempered in the bath at 430°; on trial they were found too soft. They were a second time hardened, and then heated to 212°. The intention was to increase the heat from that point, trying the temper at the advance of about every ten degrees. In the present instance this was not necessary, the heat of boiling water proving to be the exact point, at which the knife edges were admirably tempered.

It is highly probable that steel, for many uses, may be sufficiently tempered in a range so extensive as from 212° to 430°, and, by the thermometer, all the intervening degrees may certainly be ascertained.

That the colour produced on the surface of heated steel is the effect of oxidation, is proved from the circumstance that when steel is heated and suffered to cool under mercury or oil, none of the colours appear ; nor do they when it is heated in hydrogen or in nitrogen.

764. Steel is improved by combination with some other of the metals, forming valuable alloys. (See SILVER.) They seem to require some difference in treatment from the workman, particularly in tempering. —*Quarterly Journal of Science*, Vol. ix. p. 319.

SECTION X. *Zinc.*

765. ZINC is found in the state of oxide and of sulphuret. It may be obtained pure by dissolving the zinc of commerce in dilute sulphuric acid, and immersing a plate of zinc for some hours in the solution, which is then filtered, decomposed by carbonate of potassa, and the precipitate ignited with charcoal in an iron or earthen retort.

Common zinc generally contains a portion of lead, copper, iron, traces of arsenic and manganese, and a little plumbago : these impurities remain in the form of a black powder when it is dissolved in dilute sulphuric acid.

Zinc is a bluish white metal, sp. gr. 7, malleable at 300°, but very brittle when its temperature approaches that of fusion, which is about 680°. It is somewhat ductile, but its wire possesses little tenacity.

766. *Oxide of Zinc* is obtained by heating the metal exposed to air. At a red heat it takes fire, burns with a bright flame, and is converted into a white flocculent substance, formerly called *pompholix*, *nihil album*, *philosopher's wool*, and *flowers of zinc*. It consists of 33 zinc + 7.5 oxygen. This oxide is white, tasteless, and soluble in the alcalis. As prepared by combustion it contains small particles of the metal, which always render it gritty; hence, for pharmaceutical use, it is best prepared by precipitating solution of sulphate of zinc by ammonia, and washing and drying the precipitate. It is sometimes used as a pigment, both with oil and water; and is employed in medicine as a tonic, and as an external application.

767. The representative number of zinc was obtained by dissolving 100 grains of pure zinc in nitric acid, evaporating to dryness and keeping the residue at a dull red heat till it ceased to lose weight: 122.75 grains of oxide of zinc were thus obtained, and 22.75 : 100 : : 7.5 : 32.97. So that the number 33, which very nearly coincides with Dr. Davy's analysis of the chloride, (*Phil. Trans.* 1812.) may be adopted without material error.

768. *Chloride of Zinc* is formed by heating leaf zinc in chlorine, or by evaporating muriate of zinc to dryness, and heating the residue red-hot in a glass tube. It is a fusible compound, very deliquescent, and produces a *muriate of zinc* by the action of water. It does not rise at a red heat in close vessels. It consists of 33 zinc + 33.5 chlorine. It was formerly called *butter of zinc*.

The attraction of zinc for chlorine is very great, and this metal may therefore often be employed for separating chlorine from other combinations.

769. *Chlorate of Zinc* crystallizes in octoëdra, and is a very soluble salt.

770. *Muriate of Zinc* is very soluble and difficultly crystallizable: heated in the air it loses muriatic acid and leaves oxide of zinc: in a close vessel it loses water and leaves chloride of zinc.

771. *Iodine and Zinc* readily combine, and produce a fusible, volatile, and crystalline compound, which, when exposed to air, deliquesces into *hydriodate of zinc.*

The iodide consists of 33 zinc + 117.7 iodine; and the hydriodate may be regarded as consisting of one proportional oxide of zinc = 40.5 + one proportional hydriodic acid = 118.7.

772. *Iodate of Zinc.*—When iodate of potassa is added to solution of sulphate of zinc, it forms an insoluble iodate of zinc.

773. *Nitrate of Zinc* is a deliquescent salt, which crystallizes with difficulty in four-sided prisms. They are copiously soluble in water and alcohol, and consist of

40.5	oxide
50.5	nitric acid
91	

774. Liquid ammonia readily dissolves oxide of zinc, and even acts upon the metal. The concentrated solution of the oxide furnishes feathery crystals; it is decomposed by the acids, and the immersion of a plate

of copper causes a precipitation of part of the zinc, the ammonia acquiring at the same time a blue colour.—De Lassone, *Annales de Chimie*, xxxv. 53.

775. *Sulphuret of Zinc* exists native under the name of *Blende*. It may be formed artificially by heating oxide of zinc with sulphur, and is then of a yellow brown colour. It consists of 33 zinc + 15 sulphur.

Blende is a brittle soft mineral, of different shades of brown and black. Its primitive form is the rhomboidal dodecaëdron. It usually contains traces of iron and lead. It is an abundant mineral, and important as a source of the pure metal, which is obtained by roasting the ore, and afterwards exposing it to heat in proper distillatory vessels, mixed with charcoal (783). The English miners call it *black jack*.

776. *Hyposulphite of Zinc* was formed long ago by Fourcroy, who considered it as a *sulphuretted sulphite*. He formed it by digesting metallic zinc in sulphurous acid, sulphuretted hydrogen is disengaged, and by gentle evaporation crystals are obtained, which are to be digested in alcohol; this liquid dissolves the hyposulphite, and affords it in prismatic crystals. A mixture of oxide of zinc and sulphur treated by sulphurous acid affords the same salt; it is efflorescent, and easily decomposed by heat.—Fourcroy, *Système des Connoissances Chimiques*, v. 380.

777. *Sulphite of Zinc* is easily formed by dissolving the oxide in sulphurous acid; it is more easily crystallizable than the hyposulphite, and is insoluble in alcohol.

778. *Sulphate of Zinc.*—The metal is readily oxidized and dissolved by dilute sulphuric acid, hydrogen

gas is given off, and a transparent colourless solution of sulphate of zinc results, which, by evaporation, affords crystals in the form of four-sided prisms, terminated by four-sided pyramids.

This salt is soluble in 2.5 parts of water at 60°. It consists of 1 proportional of oxide = 40.5 + 1 proportional of acid = 37.5. Its crystals contain 7 proportionals of water = 59.5. Sulphate of zinc is prepared for the purposes of the arts from the native sulphuret, and is usually in the form of a white amorphous mass, called *white vitriol.*

Native Sulphate of Zinc is found at Holywell in Flintshire, and in other places where the sulphuret of zinc occurs; it is probably the result of the decomposition of that ore.

779. *Phosphuret of Zinc* is a brilliant lead-coloured compound.

780. Neither *Hypophosphite* nor *Phosphite of Zinc* have been examined.

781. *Phosphate of Zinc* is not crystallizable. It may be obtained by dissolving zinc in phosphoric acid, and evaporation to dryness. A phosphate of zinc is also precipitated upon the addition of phosphate of soda to sulphate of zinc. These salts have not been precisely examined, but it is probable there is a phosphate and a bi-phosphate of zinc.

782. *Carbonate of Zinc* occurs native, forming one of the varieties of the mineral called *calamine.* It may be formed by adding carbonate of potassa to sulphate of zinc. It consists of 40.5 oxide of zinc + 20.7 carbonic acid = 61.2. It is white and tasteless.

The primitive form of calamine, which occurs both crystallized and massive, is an obtuse rhomboid. It is often found investing carbonate of lime, which has sometimes been decomposed, and the calamine remains in pseudo-crystals. This mineral abounds in Somersetshire, Flintshire, and Derbyshire. A beautiful variety, coloured by carbonate of copper, is found at Matlock. A variety of calamine, containing siliceous earth, is known by the name of *electric calamine*, from its property of becoming electrical when gently heated.

783. The zinc of commerce is procured from the native sulphuret and from calamine by the following process. The ore is first picked and broken into small pieces, and then submitted to a dull red heat in a reverberatory furnace, by which carbonic acid is driven off from the calamine, and sulphur from the blende. It is then washed, ground, and thoroughly mixed with about one eighth its weight of powdered charcoal. This mixture is put into large earthen pots, not unlike oil jars, six of which are usually placed in a circular furnace; each pot has an iron tube passing from its lower part, through the floor of the furnace, and dipping into water; they are every where else firmly luted: upon the application of a red heat, the metal distils through the tube into the water beneath, whence it is collected, melted, and cast into cakes.

784. *Borate of Zinc* is an insoluble white powder.

785. Ferrocyanate of potassa produces a yellowish white precipitate in solutions of zinc.

786. The salts of zinc are mostly soluble in water, and the solutions are colourless and transparent: they are not precipitated by hydriodic acid. Potassa, soda, and ammonia, form white precipitates, soluble in excess

of the alcali, and sulphuric acid. Hydrosulphuret of ammonia produces a yellowish white precipitate. The soluble phosphates, carbonates, and borates, produce white precipitates.

787. *Alloys of Zinc.*—With potassium and sodium zinc forms brittle alloys, decomposable by exposure to air and water. Its alloy with manganese is unknown. With iron it forms a white and somewhat malleable alloy, which is difficult to form; but if plates of hot iron be dipped into melted zinc, they acquire the appearance of tin-plate.

SECTION XI. *Tin.*

788. THIS metal has been known from the remotest ages. It was in common use in the time of Moses, and was obtained at a very early period from Spain and Britain by the Phœnicians.—PLINY, lib. iv. cap. 34, and xxxiv. cap. 47.

The native oxide is the principal ore of tin; the metal is obtained by heating it to redness with charcoal. The process is described at length in AIKIN's *Dictionary*, (*Art.* TIN.)

Tin has a silvery white colour; it is malleable, though sparingly ductile. Sp. gr. 7.30. It melts at 440°, and by exposure to heat and air is gradually converted into a white peroxide. Placed upon ignited charcoal under a current of oxygen gas, it burns very brilliantly.

789. A preparation under the name of *powdered tin* is sometimes directed to be prepared for pharmaceutical use, by shaking the melted metal in a wooden box rubbed with chalk on the inside: *tin filings* have also a place in some *Pharmacopœiæ,* and have been used as a vermifuge. These preparations are, however, both dangerous, the metal being rendered poisonous in the former case by slight oxidation, (ORFILA, *Traité des Poisons,* T. i., 2me partie, p. 18.) and often creating very dangerous irritation when given in filings.

790. *Protoxide of Tin* is obtained by precipitating protomuriate of tin by ammonia; it falls in the state of hydrate; when dried, it is of a grey colour, and undecomposable by heat. It dissolves in the alcalis; exposed to heat and air it passes into the state of peroxide, undergoing a faint combustion. Its ammoniacal solution, when long kept, deposits metallic tin in arborescent crystals, and becomes a solution of the peroxide.

791. *Peroxide of Tin* is formed by treating the metal with nitric acid: there is a violent action attended by the formation of nitrate of ammonia. (287). Scarcely any of the metal is dissolved, but remains as a yellowish powder, which may be purified by washing. It is also formed by heating tin filings with red oxide of mercury; and by projecting a sufficient quantity of nitre upon red-hot tin. This oxide dissolves in the alcalis. Fused with glass it forms *White Enamel.* Heated intensely it becomes insoluble in acids, and undergoes fusion.

The substance called *Tin Putty*, is an oxide of tin formed by levigating the crusts of oxide that form upon the metal when kept for some time in fusion.

792. *Native Oxide of Tin* is found in Cornwall; in Spain; and in Saxony: it has also been found in Brittany, in France; in the East Indies; and in South America. The specific gravity of the native oxide is 7: its primitive crystal is an obtuse octoëdron, of which the modifications are extremely numerous. (W. Phillips, *Geological Transactions*, Vol. ii.) In some of the valleys of Cornwall, tin is found in rounded nodules, of various sizes, mixed with pebbles and rounded fragments of rocks. To separate the tin from the alluvial matter, currents of water are passed over it, and hence these deposits have been called *stream works*, and the tin ore, *stream tin*. One of the most extensive of these is a branch of Falmouth Harbour. A modification of stream tin is called *wood* tin. It usually appears in small banded fragments of globular masses.

793. The number representing tin is 55.5. The protoxide consists of 55.5 tin + 7.5 oxygen. The hydrate of 63 protoxide + 8.5 water; and the peroxide of 55.5 tin + 15 oxygen. These numbers are deduced from the accurate analyses of Dr. John Davy (*Phil. Trans.*, 1812) and M. Gay-Lussac. (*Annales de Chimie*, lxxx.) The protoxide of tin, according to both these chemists, consisting of 100 tin + 13.5 oxygen; and the chloride, according to John Davy, of 100 tin + 60.71 chlorine.

794. *Chloride of Tin* is procured by heating together an amalgam of tin and calomel; or more simply

by heating protomuriate of tin in a retort till it fuses; it is a grey semi-transparent crystalline solid, which dissolves in water, forming a protomuriate of tin; it is volatile at a red heat; it consists of 55.5 tin + 33.5 chlorine. Heated in chlorine it burns into perchloride of tin.

795. If tin be heated in chlorine, or if amalgam of tin be distilled with corrosive sublimate, a *perchloride* is obtained. The best proportions are six parts of tin, previously combined with one of mercury, and intimately mixed with thirty of corrosive sublimate. The mixture is put into a glass retort with a sufficiently capacious receiver luted to it, and may be distilled over a small charcoal fire. The heat should be slowly raised to prevent too sudden action. Towards the end of the process a little chloride rises, which the old chemists, from its consistency and appearance, called *Butter of Tin.* It is a transparent colourless fluid, and when poured into water, is instantly converted into permuriate of tin. It consists of 55 tin + 67 chlorine. It was formerly called *Libavius's Fuming Liquor*: it exhales copious fumes when exposed to a moist air, and produces muriatic acid and oxide of tin. It is instantly decomposed by metallic zinc, forming chloride of zinc and a precipitate of metallic tin.

796. *Chlorate of Tin* has not been examined.

797. The *Protomuriate of Tin,* used by dyers, may be obtained by boiling one part of tin with two of muriatic acid. This solution quickly absorbs oxygen from the air and from several compounds, and if added to certain metallic solutions, revives or deoxidizes them. With solution of gold it produces a purple precipitate

used in painting porcelain, and known under the name of *Purple of Cassius.* It crystallizes from its concentrated solution in small deliquescent needles. With infusion of cochineal it produces a purple precipitate. This muriate of tin is the *Sal Jovis* of old writers, Jupiter being the name by which the alchymists distinguished this metal.

When potassa is added to muriate of tin, a *submuriate* of the protoxide is thrown down, containing, according to J. Davy,

70.4	protoxide
19	muriatic acid
10.6	water
100.0	

798. The *Permuriate of Tin* (muriate containing the peroxide) may be formed by dissolving the metal in nitro-muriatic acid, or by exposing the muriate to air. It forms acicular crystals in the upper parts of phials containing the bi-chloride imperfectly secured from air; and is directly formed by adding water to the bi-chloride, which excites much heat, and forms a concrete mass easily fusible and soluble in water. It does not occasion precipitates in the metallic solutions, and produces a scarlet colour with infusion of cochineal.

799. The pure alcalis added to this salt of tin, occasion a precipitate which has not been accurately examined, but is said to be a *subpermuriate.* The peroxide of tin is more readily soluble in alcalis than the protoxide; it has been hence termed *Stannic Acid.*

800. *Iodide of Tin* may be formed directly by

heating the metal with iodine; or indirectly by adding hydriodic acid to a solution of muriate of tin. It is an orange-coloured compound, and has not been analyzed.

801. *Iodate of Tin* has not been examined.

802. *Nitrate of Tin* may be formed by acting upon the metal by dilute nitric acid; a yellow solution which will not crystallize is obtained; exposed to air it absorbs oxygen, and peroxide of tin precipitates. If evaporated, the peroxide falls, and a portion of nitrate of ammonia is formed. It is evident therefore that part of the water, as well as of the acid, are here decomposed.

803. *Tin and Sulphur.*—There are two sulphurets of tin. That containing 1 proportional of metal + 1 of sulphur, may be procured by heating tin with sulphur; it is of a deep bluish colour and crystallizes in long needles.

804. *Bi-sulphuret of Tin* is of a bright golden yellow colour, and flaky structure, and has been termed *Aurum Musivum.* It is formed by heating peroxide of tin with its weight of sulphur. Mr. Woulfe has given a formula for its production, (*Phil. Trans.*, 1771) but the following, taken from the *London New Dispensatory* of 1765, answers best. Take 12 oz. of tin and amalgamate it with 6 oz. of mercury, reduce it to powder, and mix it with 7 oz. of flowers of sulphur and 6 oz. of sal ammoniac, and put the whole into a glass matrass placed in a sand heat. Apply a gentle heat till the white fumes abate, then raise the heat to redness, and keep it so for a due time. On cooling and breaking the matrass, the *Mosaic gold* is found

at the bottom.—*See* WOULFE's *Paper, and* AIKIN's *Dict.: Art.* TIN.

The sulphurets of tin consist respectively of 55 tin + 15 sulphur, and 55 tin + 30 sulphur.

805. *Hyposulphite of Tin*, has not been examined. Muriate of tin forms no precipitate with the alcaline hyposulphites.

806. *Sulphite of Tin* is formed by digesting the protoxide in sulphurous acid, but the salt has not been examined.

807. *Sulphate of Tin.*—When tin is boiled in sulphuric acid, a solution is obtained which deposits white acicular crystals. A protosulphate of tin is also precipitated by pouring sulphuric acid into protomuriate of tin.

808. *Hydrosulphuretted Oxide of Tin* is yellow brown, and formed by pouring solution of sulphuretted hydrogen into dilute muriate of tin.

809. *Phosphuret of Tin* may be formed by dropping phosphorus into melted tin. It is of a silvery colour, sectile, and somewhat ductile. When its filings are sprinkled upon hot coals the phosphorus burns.

810. *Phosphite of Tin* has not been examined.

811. *Phosphate of Tin* is formed by adding phosphate of soda to the solutions of tin. It is a white powder, not soluble in water, and fuses at a red heat into an opaque white enamel.

812. *Carbonate of Tin.*—When carbonate of potassa is added to protomuriate of tin, a white precipitate ensues, which, when washed and dried, effervesces copiously with the acids.

813. *Borate of Tin* is an insoluble white powder.

814. Ferrocyanate of potassa produces a white precipitate in solution of muriate of tin.

815. The salts of tin are mostly soluble in water. They are precipitated, of an orange colour, by hydriodic acid, and by hydrosulphuret of ammonia, provided no excess of acid be present. Solution of muriate of gold, and of corrosive sublimate, produce purple and black precipitates in the salts of tin containing the protoxide, but none in those containing the peroxide.

816. *Alloys of Tin.*—With potassium and sodium tin forms brittle white alloys. Its alloy with manganese is not known. It does not readily combine with iron, but tin-plate (756) may be considered as an imperfect alloy of those metals. With zinc it forms a hard brittle alloy.

Section XII. *Cadmium.*

817. This metal is contained in certain ores of zinc, and especially in the black fibrous Blende of Bohemia. It may be procured by digesting the ore in muriatic acid, by which a mixed muriate of zinc and cadmium is obtained: it should be evaporated to dryness, and re-dissolved in water. If cadmium be present, the solution affords a bright yellow precipitate with sulphuretted hydrogen; and upon immersing into it a

plate of zinc, metallic cadmium is precipitated, which may be fused into a button in the usual way.

The simplest method of detecting cadmium is the following, devised by Dr. Wollaston. Digest the ore in muriatic acid, filter, and evaporate to dryness: re-dissolve the dry mass in water, filter, and put a cylinder of iron into the clear solution to precipitate all metals thus separable: filter again, and immerse a cylinder of zinc, which will throw down metallic cadmium, and which, when re-dissolved in muriatic acid, exhibits its peculiar characters.

818. The physical properties of cadmium closely resemble those of tin: its specific gravity is 8.63. It fuses and volatilizes at a temperature a little below that required by tin. Air does not act upon it except when heated, when it forms an orange-coloured oxide, not volatile, and easily reducible.

819. *Oxide of Cadmium* readily dissolves in acids; it is precipitated by potassa in the state of a white hydrated oxide, soluble in ammonia. Sulphuretted hydrogen forms a yellow precipitate in the solution of cadmium, and zinc throws down metallic cadmium.

From the experiments of Mr. Children, it appears that the oxide contains

Cadmium	82.5
Oxygen	7.5

Consequently, the representative number of the metal will be 82.5.

The other compounds of cadmium have scarcely been examined.

SECTION XIII. *Copper.*

820. THIS metal is found native, and in various states of combination. Of its ores, the oxide, chloride, sulphuret, sulphate, phosphate, carbonate, and arseniate, are the most remarkable. The metal may be obtained perfectly pure by dissolving the copper of commerce in muriatic acid; the solution is diluted, and a plate of iron is immersed upon which the copper is precipitated. It may be fused into a button, after having been previously washed in dilute sulphuric acid to separate a little iron that adheres to it.

It was known in the early ages of the world, and was the principal ingredient in domestic utensils, and in the instruments of war, previous to the discovery of malleable iron. The word *copper* is derived from the island of Cyprus, where it was first wrought by the Greeks.

821. Copper has a fine red colour and much brilliancy; it is very malleable and ductile, and has a peculiar smell when warmed or rubbed. It melts at a cherry red or dull white heat. Its specific gravity is 8.89. Under a flame, urged by oxygen gas, it takes fire, and burns with a beautiful green light.

822. Exposed for a long time to damp air, copper becomes covered with a thin greenish crust of carbonate. If heated and plunged into water, a quantity of reddish scales separate, consisting of an imperfect

oxide. The same scales fly off during cooling from a plate of the metal which has been heated red hot.

823. *Native Copper* occurs in a variety of forms; massive, dendritic, granular, and crystallized in cubes, octoëdra, *&c.* It is found in Cornwall, Siberia, Saxony, Hanover, Sweden, and America; chiefly, but not exclusively, in primitive rocks.

824. *Copper and Oxygen.*—There are two oxides of copper. The red or *Protoxide* occurs native. It may be formed artificially, by digesting a mixture of metallic copper, and peroxide of copper, in muriatic acid. When potassa is added to this solution, a *hydrated protoxide,* of an orange colour, falls; if quickly dried out of the contact of air, it becomes of a red brown: it consists of 60 copper + 7.5 oxygen = 67.5.

825. The *Native Protoxide,* or *Ruby Copper,* is of a red or steel-grey colour, soft and brittle, and occurs massive, and crystallized in octoëdra, dodecaëdra, and cubes. There is a beautiful variety in fine capillary crystals; and another, which is compact and earthy, called *Tile Ore.* Cornwall abounds in fine specimens of this ore.

826. *Peroxide of Copper* is procured by precipitating nitrate of copper by potassa, washing the precipitate, and exposing it to a red heat. It is black, and consists of 60 copper + 15 oxygen = 75.

827. The composition of this oxide is learned by dissolving 100 grains of pure copper in nitric acid, evaporating to dryness, and giving the residue a red heat in a porcelain crucible; it is peroxide of copper, and weighs 125 grains: considering this as a compound of 1 proportional of copper and 2 of oxygen,

the number 60 will represent the metal; for, 25 : 100 :: 15 : 60.

100 grains of pure native protoxide of copper in octoëdral crystals, dissolved in muriatic acid, furnished a precipitate of 89 grains of metallic copper upon a plate of iron, so that the protoxide consists of 89 copper + 11 oxygen; and 11 : 89 :: 7.5 : 60.

This number closely accords with that derived from the analysis of the chloride.

828. *Copper and Chlorine.*—Gaseous chlorine acts upon copper with great energy, and produces two chlorides; the one a fixed fusible substance, which is the protochloride, consisting of 1 proportional of copper = 60 + 1 proportional of chlorine = 33.5. The other a volatile yellow substance, which is a perchloride, and contains 60 copper + 67 chlorine.

829. The *Protochloride of Copper* was first described by Boyle in 1666, under the name of *Rosin of Copper*. It may be obtained by exposing copper filings to the action of chlorine not in excess; or by evaporating the protomuriate, and heating the residue in a vessel with a very small orifice; or by heating the perchloride in the same way. It is also the residue of the distillation of a mixture of two parts of corrosive sublimate and one of copper filings. It is insoluble in water, but soluble in muriatic acid, from which potassa throws down a protoxide. When water is added to its muriatic solution it is precipitated unaltered: its colour varies, being generally dark brown; but if fused and slowly cooled, it is yellow, translucent, and crystalline.

830. When moistened chloride of copper is exposed

to air it acquires a greenish white colour, and becomes converted into a *subpermuriate of copper*. The same compound may be formed by adding hydrated peroxide of copper to a solution of the permuriate; or by exposing to the atmosphere slips of copper partially immersed in muriatic acid. This compound consists of

2	proportionals peroxide of copper	75 × 2 = 150
1	———— muriatic acid	34.5
2	———— water	17
		201.5

831. *Perchloride of Copper* may be formed by dissolving peroxide of copper in muriatic acid, and evaporating to dryness by a heat below 400°. It is soluble in water, producing a permuriate, from which potassa precipitates the peroxide: its colour is yellow, but it becomes white and afterwards green when exposed to heat and moisture. Exposed to a red heat in a tube with a very small orifice, gaseous chlorine is expelled and it becomes a protochloride.

832. Muriatic acid acts with difficulty on metallic copper, except it be concentrated and boiling; but it readily dissolves the peroxide, forming a brown or grass-green solution, according to its state of dilution. This is a *permuriate of copper*. If plates of copper be exposed to the joint action of air and the fumes of muriatic acid, they become incrusted with a green powder, which is readily soluble in muriatic acid, and which may be termed a *subpermuriate*. (830.)

If metallic copper be digested in muriatic acid with the peroxide, an olive-coloured solution of *protomuriate of copper* is formed which strongly attracts oxygen, and which when concentrated deposits small grey crystals. The addition of potassa occasions a precipitate of the orange or protoxide of copper, (824) which, according to Berzelius, consists of 100 copper + 12.5 oxygen. (*Annales de Chim.*, lxxviii. 107.) Proust's analysis of the peroxide gives 100 copper + 25 oxygen, and these numbers furnish 60 as the equivalent of copper. (827.)

833. *Native Submuriate of Copper* is found in Peru and Chili, sometimes in the form of green sand, and sometimes massive and crystallized. The green sand was found in the river Lipas, in the desert of Atacama, separating Peru from Chili, hence mineralogists have termed this variety, *Atacamite.* Muriate of copper has also been found upon some of the lavas of Vesuvius. The primitive form of this substance is an octoëdron. It is of a deep green colour, and contains, according to Dr. Davy's analysis,

73	peroxide of copper
16.2	muriatic acid
10.8	water
100	

834. *Chlorate of Copper* is a blue-green deliquescent salt, difficultly crystallizable, formed by dissolving peroxide of copper in chloric acid. A piece of paper dipped into its solution burns with a remarkably green flame.—VAUQUELIN.

835. An *Iodide of Copper* is precipitated from solutions of the metal by hydriodic acid. It is brown and insoluble.

836. When solution of iodate of potassa is added

to solutions of copper, an insoluble *iodate of copper* is thrown down.

837. *Nitrate of Copper.*—Nitric acid, diluted with three parts of water, rapidly peroxidizes copper, evolving nitric oxide, and forming a bright blue solution, which affords deliquescent prismatic crystals on evaporation, of a fine blue colour and very caustic. It consists of 75 peroxide + 101 acid; but the crystals contain a considerable portion of water, which causes them to liquefy at a temperature below 212°. At a higher temperature they lose water and acid, and according to Proust become a *subpernitrate,* which is insoluble in water, and entirely decomposed at a red heat. There appears to be no protonitrate of copper, for protoxide of copper, digested in very dilute nitric acid, is resolved into peroxide which dissolves, and into metallic copper. Potassa forms, in this solution, a bulky blue precipitate of *hydrated peroxide of copper,* which, when boiled in potassa or soda, becomes black from the loss of its combined water.

838. When crystals of nitrate of copper are coarsely powdered, sprinkled with a little water, and quickly rolled up in a sheet of tin-foil, there is great heat produced, nitrous gas is rapidly evolved, and the metal often takes fire.

839. If ammonia be added to solution of nitrate of copper, it occasions a precipitate of the hydrated peroxide; but if it be added in excess, the precipitate is re-dissolved, and a triple *ammonio-nitrate of copper* is produced.

840. If peroxide of copper be digested in ammonia it is dissolved, forming a bright blue solution, which by careful evaporation affords fine blue crystals. A

mixture of lime, sal ammoniac, and water, placed in a copper vessel, or mixed with oxide of copper, also affords a fine blue liquor in consequence of the action of the ammonia on the oxide of copper. This solution is the *Aqua Sapphirina* of old pharmacy. The compound has sometimes been called *Ammoniuret of Copper*, or *Cuprate of Ammonia.*

841. The protoxide of copper also dissolves in ammonia, but the solution is colourless; if it be exposed to air it becomes blue. This may be well shown by filling a tall glass with liquid ammonia, and adding a few drops of solution of protomuriate of copper; the liquid presently acquires a blue colour upon the surface, but remains for some time colourless below.

842. Plates of copper digested in a solution of muriate of ammonia, are soon incrusted with a green powder, which has been used in the arts under the name of *Brunswick green.*

843. *Copper and Sulphur.*—There are two sulphurets of copper, both of which exist native; the one is black, and may be formed artificially, by heating a mixture of copper filings and sulphur: as soon as the latter melts, a violent action ensues, the copper becomes red hot, hydrogen escapes, and a black brittle body is formed, consisting of 60 copper + 15 sulphur*.

The *bi-sulphuret* is a common ore of copper, called *pyrites.* It consists of 60 copper + 30 sulphur, and is of a golden yellow colour.

844. The *Native Black Sulphuret of Copper* is principally found in primitive countries. In England,

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* The hydrogen appears to be derived from the sulphur. (343.)

it occurs in great beauty, crystallized and massive, in Cornwall, and in Yorkshire. Its colour is grey; its lustre shining and metallic, and it yields easily to the knife. Its primitive form is a six-sided prism, which passes into the dodecaëdron with triangular faces, and various modifications of it.

A variety of black sulphuret of copper, containing iron and arsenic, has been described by Messrs. W. and R. Phillips. It has been termed by the latter *Tennantite;* its most ordinary form is the rhomboidal dedocaëdron, either perfect or variously modified.—*Quarterly Journal of Science and Arts,* Vol. vii., p. 95.

845. *Copper pyrites,* or the yellow sulphuret of copper, is the most important and generally occurring ore, from which the largest proportion of the copper of commerce is derived; it occurs in a variety of forms, its primitive crystal being the regular tetraëdron. The Cornish mines are very productive of this ore, and it is the principal product of the Parys mountain mine in Anglesea. A beautiful iridescent variety occurs in the Ecton mine in Staffordshire.

846. The following is an outline of the process by which these ores of copper are reduced, as carried on upon a very large scale near Swansea, where the chief part of the Cornish ores are brought to the state of metal. The ore, having been picked and broken, is heated in a reverberatory furnace, by which arsenic and sulphur are driven off. It is then transferred to a smaller reverberatory, where it is fused, and the slag which separates, being occasionally removed, is cast into oblong masses used as a substitute for bricks. The impure metal collected at the bottom of the furnace is granulated by letting it

run into water; it is afterwards re-melted and granulated two or three times successively, in order further to separate impurities, which are chiefly sulphur, iron, and arsenic, and ultimately cast into oblong pieces called *pigs*, which are broken up, roasted, and lastly melted with a portion of charcoal in the refining furnace. It is now malleable: and is generally rolled into plates, which are annealed, and when hot, quenched in urine, which gives the metal a peculiar red tinge.

847. *Hyposulphite of Copper* was formed by Mr. Herschel by mixing hyposulphite of potassa with sulphate of copper. It is colourless; of an intensely sweet taste; and provided air be excluded, it is not turned blue by ammonia, which seems to show that the metal is in the state of protoxide.—*Edinburgh Philosophical Journal*, i. 24.

848. *Sulphite of Copper* may be obtained by passing sulphurous acid into water through which oxide of copper is diffused. Small red crystals are formed, composed of protoxide of copper and sulphurous acid. —Chevreuil, *Annales de Chimie*, lxxxiii.

849. When sulphite of potassa is added to nitrate of copper a precipitate falls, which assumes the form of red and yellow crystals. The former are sulphite of copper; the latter a triple *sulphite of potassa and copper*.—Chevreuil.

850. *Persulphate of Copper—Roman Vitriol—Blue Vitriol.*—This salt is formed by dissolving peroxide of copper in sulphuric acid. It crystallizes in rhomboidal prisms of a fine blue colour, doubly refractive, and soluble in about 4 parts of water at 60°. It may also be formed by boiling copper filings in sul-

phuric acid; a process which furnishes abundance of sulphurous acid, but which is not generally had recourse to, to produce sulphate of copper. It is made upon a large scale, by exposing roasted sulphuret of copper to air and moisture. When heated it loses water of crystallization, and at a higher temperature sulphuric acid is evolved, unmixed with sulphurous acid, as in the case of the decomposition of protosulphate of iron (738), and peroxide of copper remains. It is the *Vitriol* or *Salt of Venus* of the alchymists. It consists of 75 peroxide + 75 sulphuric acid; when crystallized it contains 10 proportionals of water, and consequently its composition will stand thus:—

1 proportional of peroxide.....	75
2 proportionals of sulphuric acid	75
10 proportionals of water.......	85
	235

There appears to be no *protosulphate* of copper, for when protoxide of copper is digested in dilute sulphuric acid, metallic copper is separated, and a solution of the peroxide obtained.

851. By cautiously adding ammonia to a solution of the foregoing salt, a *subsulphate of copper* is precipitated, consisting of 150 oxide + 37.5 acid. The alcalis precipitate hydrated peroxide from the solution of the persulphate, and excess of ammonia forms a *triple sulphate of ammonia and copper*. The same compound is formed by triturating carbonate of ammonia with crystals of sulphate of copper. It is the *cuprum ammoniatum* of the *Pharmacopœia*.

852. *Sulphate of Copper and Potassa* is a triple salt formed by digesting peroxide of copper in bisulphate of potassa. It crystallizes in rhomboids of a pale blue colour.

853. *Phosphorus and Copper* form a grey brittle phosphuret. It is most easily made by dropping pieces of phosphorus on red-hot copper wire. It is more fusible than copper.

854. Neither the *hypophosphite* nor *phosphite of copper* have been examined.

855. *Phosphate of Copper* may be formed by mixing solution of sulphate of copper with phosphate of soda; it is a bluish green insoluble powder, composed, as would appear from Mr. Chenevix's analysis, (*Phil. Trans.* 1803.) of

1	proportional peroxide of copper	75
2	———— phosphoric acid....	52
1	———— water	8.5
		135.5

856. *Native Phosphate of Copper* has been found near Cologne. It is of a green colour, and forms small rhomboidal crystals.

857. *Carbonate of Copper*, artificially prepared, by adding carbonate of potassa to sulphate of copper and drying the precipitate, is a green compound, insoluble in water, consisting, according to Mr. R. Phillips, of 75 peroxide + 20.7 carbonic acid + 8.5 water. It is, therefore, a *subpercarbonate*. Copper, exposed to damp air, becomes incrusted with this compound. Exposed to heat, it loses water and carbonic acid, and leaves the peroxide. In order to heighten the green tint for which

this compound is esteemed as a pigment, it should be repeatedly washed with boiling water.

858. There is a fine blue cupreous preparation, called *Refiners' Verditer*, principally made by silver refiners. It consists, according to Mr. R. Phillips, of 3 proportionals of oxide, 4 of carbonic acid, and 2 of water. (*Quarterly Journal of Science and Arts*, Vol. iv. p. 277.) There is a very inferior pigment, also called Verditer, which is a mixture of subsulphate of copper and chalk.

According to Pelletier, a good verditer may be obtained as follows: add a sufficient quantity of lime to nitrate of copper to throw down the hydrated oxide; it gives a greenish precipitate that is to be washed and nearly dried upon a strainer; then incorporate with it from 8 to 10 *per cent.* of fresh lime, which will give it a blue colour, and dry it carefully.

859. According to Mr. Chenevix, the alcaline carbonates dissolve a portion of the peroxide of copper, and form triple salts.

860. *Native Carbonate of Copper* is found of a green and blue colour. The former, or *Malachite*, is found in various forms, but never regularly crystallized, the octoëdral variety being a pseudo-crystal derived from the decomposition of the red oxide. This mineral occurs in the greatest beauty in the Uralian mountains of Siberia; it is rarely found in Cornwall. It is of various shades of green, and often cut into small slabs, or used as beads and broach stones. The pulverulent variety has been termed *chrysocolla* and *mountain green*.

The blue carbonate is found in great perfection at

Chessy near Lyons; also in Bohemia, Saxony, *&c.* It occurs crystallized in rhomboids and imperfect octoëdra; it also is found in small globular masses; massive; and earthy. The earthy variety is sometimes called *copper azure* or *mountain blue.*

The *Dioptase* or *Emerald Copper* is a very rare mineral, hitherto found only in Siberia, associated with malachite. It consists, according to Lowitz, of oxide of copper, silica, and water.

861. *Borate of Copper.*—Solution of borax, poured into sulphate of copper, produces a bulky pale green precipitate of borate of copper.

862. *Ferrocyanate of Copper* is a brown compound, obtained by adding ferrocyanate of potassa to a dilute solution of sulphate or nitrate of copper. Mr. Hatchett has recommended this substance as a brown pigment.

863. Many of the alloys of copper are important. With gold it forms a fine yellow ductile compound, used for coin and ornamental work. Sterling or standard gold consists of 11 gold + 1 copper. The specific gravity of this alloy is 17.157. With silver it forms a white compound, used for plate and coin. Lead and copper require a high red heat for union; the alloy is grey and brittle.—See *Gold* and *Silver.*

Of the alloys of copper with the preceding metals the most important are brass and bell-metal. It forms white compounds with potassium and sodium; a reddish alloy with manganese; and a grey one with iron.

864. *Brass* is an alloy of copper and zinc. The metals are usually united by mixing granulated copper with calamine (782) and charcoal: the mixture is

exposed to heat sufficient to reduce the calamine and melt the alloy, which is then cast into plates. The relative proportions of the two metals vary in the different kinds of brass; there is usually from 12 to 18 *per cent.* of zinc. Brass is very malleable and ductile when cold; and its colour and little liability to rust recommend it in preference to copper for many purposes of the arts. According to M. Sage, a very beautiful brass may be made by mixing 50 grains of oxide of copper, 100 of calamine, 400 of black flux, and 30 of charcoal powder; melt these in a crucible till the blue flame is no longer seen round the cover; and, when cold, a button of brass is found at the bottom, of a golden colour, and weighing one-sixth more than the pure copper obtained from the above quantity of oxide.

865. The analysis of brass may be performed by solution in nitric acid; add considerable excess of solution of potassa and boil, which will dissolve the oxide of zinc and leave that of copper; wash the latter, and dry and heat it to redness: 125 parts indicate 100 of copper. The zinc in the filtered alcaline solution may be precipitated by carbonate of soda, having previously added a small excess of muriatic acid; wash this precipitate, dry it, and expose it to a red heat; it is then oxide of zinc, 123 parts of which indicate 100 of metal.

866. *Tutenag* is said to be an alloy of copper, zinc, and a little iron; and *Tombac, Dutch gold, Similor, Prince Rupert's metal,* and *Pinchbeck,* are alloys containing more copper than exists in brass, and consequently made by fusing various proportions of copper with brass. According to Wiegleb, *Manheim gold* consists of 3 parts of copper and 1 of zinc. A little tin is

sometimes added, which, though it may improve the colour, impairs the malleability of the alloy.

867. *Speculum metal* is an alloy of copper and tin, with a little arsenic; about 6 copper, 2 tin, 1 arsenic. On this subject the reader is referred to Mr. Edwards's experiments.—Nicholson's *Journal*, 4to. iii.

868. *Bell metal* and *bronze* are alloys of copper and tin; they are harder and more fusible, but less malleable than copper; the former consist of 3 parts of copper and 1 of tin; the latter of from 8 to 12 of tin with 100 of copper. A little zinc is added to small shrill bells.

868*. The analysis of alloys of tin and copper may be performed by digestion in nitric acid, which dissolves the copper and converts the tin into insoluble peroxide, which, when washed and dried, consists of 100 tin + 27 oxygen. The cupreous solution may be decomposed by potassa, and the pure peroxide of copper indicates the quantity of that metal, as in the analysis of brass. (865.)

869. Vessels of copper used for culinary purposes are usually coated with tin, to prevent the food being contaminated with copper. Their interior surface is first cleaned, then rubbed over with sal-ammoniac. The vessel is then heated, a little pitch spread over the surface, and a bit of tin rubbed over it, which instantly unites with and covers the copper.

869*. The cupreous salts are nearly all soluble in water, and of a blue or green colour. Ammonia produces a compound of a very deep blue, when added in excess to these solutions; hydrosulphuret of ammonia forms a black precipitate; and a plate of iron plunged into a liquid salt of copper precipitates metallic copper.

Ferrocyanate of potassa is also an excellent test of the presence of copper; it produces a brown cloud in solutions containing the peroxide.

SECTION XIV. *Lead.*

870. THE natural compounds of this metal are very numerous. The most important is the sulphuret, from which the pure metal is chiefly procured. Lead is also found combined with carbonic, sulphuric, phosphoric, arsenic, molybdic, and chromic acids, and with oxygen and chlorine. To obtain lead perfectly pure, it may be dissolved in nitric acid; the solution evaporated to dryness; the dry mass re-dissolved in water and crystallized; these crystals heated strongly with charcoal afford the metal quite pure.

871. Lead appears to have been known in the earliest ages of the world. Its colour is bluish white. It melts at 600°, and by the united action of heat and air is readily converted into an oxide. Its specific gravity is 11.4. At common temperatures it undergoes little change by mere exposure to air, but it is slowly corroded by the joint agency of air and water. Exposed upon ignited charcoal to a current of oxygen gas, it burns with a blue flame, throwing off dense

yellow fumes of oxide. The alchymists gave this metal the name of *Saturn.*

872. *Oxides of Lead.*—There are three oxides of lead. The *protoxide* is the basis of the salts; it may be obtained pure by heating the nitrate of lead to redness in a vessel with a small orifice, till the whole of the acid is expelled. It is insipid and insoluble in water, of a pale yellow colour, and, when fused, crystallizes on cooling in irregular scales. It is volatile at a bright red heat. It is very soluble in solutions of potassa and soda; and when in fusion, it readily dissolves several of the earthy bodies, and of the common metallic oxides; hence the use of lead in *cupellation.* (885). If it be considered as a protoxide, consisting of one proportional of lead and one of oxygen, then the number 97 (deduced from the mean of the best analyses) will represent lead, and it will consist of 97 L. + 7.5 oxygen. This oxide is known in commerce under the name of *massicot;* or when vitrified, as obtained by calcining lead upon a large scale, it is called *litharge.*

When melted lead is exposed for a time to the air, it becomes incrusted with a grey pellicle, which, on removal, is succeeded by another, and so on until the whole is converted into a greenish grey powder, consisting of a mixture of the protoxide with metallic lead.

873. If the protoxide be exposed to heat and oxygen, it gradually acquires a bright red colour, and is known under the name of *minium* or *deutoxide* of lead. This oxide, when exposed to nitric acid, is resolved into protoxide, which is dissolved, and into *peroxide,* which is an insoluble brown substance, consisting of 97 L. + 15 oxygen. When peroxide of

lead is heated it gives out half its oxygen and becomes yellow protoxide.

Minium affords, on analysis, 97 L. + 11.25 oxygen, and may, therefore, be regarded as a definite compound of the protoxide and peroxide.

The minium or *red lead* of commerce generally contains a proportion of protoxide and of sulphate, with traces of chloride of lead and silica. To succeed in obtaining it of a fine red tint, it requires to be manufactured in quantities, and with several precautions. The method employed in Derbyshire is described in Watson's *Chemical Essays*, Vol. iii. p. 338.

874. A substance, supposed to be *native minium*, has been found in some of the Saxon and French lead mines, also in Yorkshire.

875. *Lead and Chlorine.—Chloride of Lead.* When laminated lead is heated in chlorine, the gas is absorbed, and a chloride of lead results, composed of 97 L. + 33.5 C. (J. Davy, *Phil. Trans.*, 1812.) The same substance is obtained by adding muriatic acid to nitrate of lead; it is white and fusible, and on cooling forms a hornlike substance (*plumbum corneum*). It volatilizes at a high temperature. It dissolves in 22 parts of water at 60°; is more soluble in boiling water, separating, as its solution cools, in small acicular crystals, unchanged by exposure to air, and of a sweetish taste. It dissolves in dilute nitric acid.

876. This substance is sometimes prepared by acting upon a solution of common salt by lithagre; solution of soda and chloride of lead are formed; the insoluble residue when fused is known under the name of *patent yellow;* it appears to be a compound of

oxide and of chloride of lead, for when treated by nitric acid, it forms nitrate of lead, and a portion of chloride separates.

877. *Native Chloride of Lead* has been found in Derbyshire and in Bavaria, crystallized in quadrangular prisms of a greenish yellow colour.

878. *Chlorate of Lead* is obtained by digesting the protoxide in chloric acid; it separates by slow evaporation, in white crystalline flakes of a very sweet taste. When heated it gives out oxygen and becomes a chloride.

879. *Iodide of Lead*, formed by heating leaf-lead with iodine, is a yellow insoluble compound. It is also formed by adding hydriodic acid or hydriodate of potassa to solution of nitrate of lead. It consists of

Iodine	117.7
Lead	97.0
	214.7

880. An insoluble *Iodate of Lead* is thrown down on adding iodate of potassa to any of the soluble salts of lead.

881. *Nitrate of Lead* is obtained by dissolving the metal, not in excess, in dilute nitric acid, and evaporation. The salt crystallizes in tetraëdra and octoëdra, which are white, translucent, and of a styptic taste. It is soluble in 8 parts of water at 212°. It consists of 104.5 oxide of lead + 50.5 nitric acid. The alcalis throw down protoxide of lead from the solution of this salt.

882. *Subnitrate of Lead* may be formed by boiling a mixture of equal weights of nitrate and protoxide of

lead in water, filtering while hot, and setting it by to crystallize; it forms pearly crystals, of a sweet astringent taste. (CHEVREUIL, *Annales de Chimie*, lxxxii.) It consists of two proportionals oxide = 209, + one proportional nitric acid = 50.5.

883. Chevreuil and Berzelius have described three *nitrites* of lead, but their composition appears doubtful. (*Ann. de Chim.*, lxxxiii. and lxxxviii.) A detailed account of them is given by Dr. Thomson.—*System*, ii. 578.

884. *Sulphuret of Lead* may be formed artificially by fusion. Its lustre and colour much resemble pure lead, but it is brittle: it consists of 97 lead + 15 sulphur.

885. *Native Sulphuret of Lead*, or *Galena*, is the principal source of the vast commercial demands of the metal. It occurs massive and crystallized, chiefly in the older secondary rocks. Its primitive form is the cube, of which there are several modifications, and among them the octoëdron. It often contains traces of silver, and sometimes in such quantity as to render it worth separating, which is effected by exposing the roasted sulphuret to the action of heat and air in shallow earthen dishes; the lead becomes oxidized and converted into litharge, while the silver is left pure, in consequence of its power of resisting the influence of heat and air. This process is called *cupellation*. The litharge is afterwards reduced by fusion with charcoal.

The reduction of galena upon a large scale is a sufficiently simple process. The picked ore, after having been broken and washed, is roasted in a reverberatory fire, the temperature being such as to soften but not fuse it. During this operation it is raked till the fumes of sulphur are dissipated, when it is brought into perfect fusion; the lead sinks to the bottom, and is run out into oblong moulds called *pigs;* the scoriæ are again melted, and furnish a portion of less pure metal.

The mines of Great Britain afford an annual produce of about 48000 tons of smelted lead, of which nearly the whole is obtained from the sulphuret.

There is a specular variety of galena, called in Derbyshire *slickensides;* and which, when touched by the miner's pick, often splits asunder with a kind of explosion.

886. *Hyposulphite of Lead* is precipitated in the form of a white powder, nearly insoluble in water, by adding solution of nitrate of lead to hyposulphite of potassa. It is composed, according to Herschel, of 70.30 protoxide of lead + 29.70 hyposulphurous acid. These numbers correspond to 1 proportional of oxide of lead = 104.5 + 2 proportionals of hyposulphurous acid = 45.

887. *Sulphite of Lead* may be obtained by digesting yellow oxide of lead in sulphurous acid; or by adding sulphurous acid or sulphite of potassa to nitrate of lead. It is white, insoluble, and tasteless, and consists of one proportional of each of its components; namely, 30 sulphurous acid + 104.5 oxide of lead. When heated it loses sulphurous acid.

888. *Sulphate of Lead.* When metallic lead is boiled in concentrated sulphuric acid, sulphurous acid is evolved, and a white sulphate of lead is formed. It is so nearly insoluble, that it may be formed by adding dilute sulphuric acid, or an alcaline sulphate, to a solu-

tion of nitrate of lead. Dr. Thomson found, that after having been dried at a temperature of 400°, it might be heated to redness in a platinum crucible without losing weight. Heated on charcoal by the blowpipe, it is decomposed and reduced. It consists of one proportional of sulphuric acid = 37.5, and one proportional of oxide of lead = 104.5; and its representative number is therefore 142. Sulphate of lead is insoluble in alcohol and in nitric acid: it is sparingly soluble in dilute sulphuric acid, and separates from it in small prismatic crystals.

889. *Native Sulphate of Lead* is found in Anglesea, and in Scotland, crystallized in prisms and in octoëdra.

890. *Hydrosulphuretted Oxide of Lead* is of a deep brown colour, and is produced by adding sulphuretted hydrogen, or hydrosulphuret of ammonia, to any solution of lead; hence the use of those compounds as tests of the presence of lead.

891. *Phosphuret of Lead* may be formed by dropping phosphorus into melted lead. It is of the colour of lead, and soon tarnishes.

892. *Hypophosphite of Lead* has not been examined.

893. *Phosphite of Lead* was prepared by Berzelius by mixing muriate of lead with phosphite of ammonia. It is white, tasteless, and insoluble, and appears to consist of 1 proportional of oxide of lead = 104.5 + 1 proportional of phosphorous acid = 18.5.

894. *Phosphate of Lead* is formed by mixing solutions of nitrate of lead and phosphate of soda, or phosphoric acid. It is yellowish white; insoluble in water; soluble in fixed alcaline solutions, and in nitric

acid. It is decomposed by sulphuric acid, and by hot muriatic acid. It fuses before the blowpipe, and crystallizes on cooling. It consists of 104,5 oxide of lead + 26 phosphoric acid = 130.5.

895. Berzelius has described a *subphosphate*, a *superphosphate*, and a *nitrophosphate of lead.—Annales de Chim. et Phys.*, ii.

896. *Native Phosphate of Lead* has been found in the mines of Cumberland, Durham, Yorkshire, and of Wanlock Head, in Scotland. Its colour is various shades of green, yellow, and brown. Its primitive form is a rhomboid, but it usually occurs in six-sided prisms. It is semi-transparent and brittle.

897. *Carbonate of Lead.*—When an alcaline carbonate is added to nitrate of lead, a white precipitate of carbonate of lead falls: it is tasteless, insoluble in water, but soluble in fixed alcaline solutions. It is employed as a white paint, under the name of *white lead* or *cerúse*, and is usually prepared by exposing sheet lead to the action of the vapour of vinegar. The process is described in AIKIN'S *Dictionary*, (*Art.* LEAD.) It consists of 104.5 oxide of lead + 20.7 carbonic acid = 125.2 carbonate of lead.

898. *Native Carbonate of Lead* is one of the most beautiful of the metallic ores: it occurs crystallized and fibrous, the former transparent, the latter generally opaque. It is soft and brittle, and occasionally tinged green with carbonate of copper, or grey by sulphuret of lead. The octoëdron is its primitive form: it also occurs prismatic and tabular. It has been found in Cumberland and Durham, and the acicular variety of great beauty in Cornwall.

899. Ferrocyanate of potassa produces a white precipitate when added to the soluble salts of lead.

900. *Borate of Lead* is precipitated in the form of a white powder, when borate of soda is mixed with nitrate of lead.

901. The soluble salts of lead have a sweetish austere taste, and are characterized by the white precipitate produced by ferrocyanate of potassa, the deep brown by hydrosulphuret of ammonia, and the yellow by hydriodate of potassa.

The salts insoluble in water are dissolved by soda and potassa, and by nitric acid, when the metal is rendered manifest by sulphuretted hydrogen and other tests. Heated by the blowpipe upon charcoal they afford a button of metal.

902. *The Alloys of Lead* with the preceding metals are not important, if we except that which it forms with tin. Common *pewter* consists of about 80 parts of tin and 20 of lead. Equal parts of lead and tin constitute *plumbers' solder;* and what is termed *pot-metal* is an alloy of lead and copper.

903. In analyzing these alloys, 100 grains in filings may be boiled to dryness in two ounces of nitric acid, water poured upon the residue, and filtered; the peroxide of tin remains in the filter, and the nitrate of lead, which passes through in solution, may be converted into sulphate by adding sulphate of soda. 142 grains of sulphate of lead dried at a red heat, indicate 97 of metal; and 70.5 grains of washed peroxide of tin are equivalent to 55.5 grains of metallic tin.

904. With potassium lead forms a brittle and very fusible alloy: with sodium the compound is equally

brittle but less fusible. When exposed to air these alloys suffer decomposition in consequence of the oxidizement of the alcaline bases. The alloy of lead and manganese has not been examined. When lead is fused with iron two alloys are obtained; that at the bottom of the crucible consisting of lead with a little iron; while the superficial portion is iron with a little lead. (Guyton Morveau, *Ann. de Chim.*, lvii.) With zinc, lead forms a hard ductile alloy.

Section XV. *Antimony.*

905. This metal is found *native* in Sweden, in France, and in the Hartz; but its principal ore is the *sulphuret* which is found massive and crystallized, and of which there are several varieties. The most common is the *radiated*, which is of a grey colour, brittle, and frequently crystallized in four and six-sided prisms. This ore may be decomposed, and the pure metal obtained from it, by the following process: Mix three parts of the powdered sulphuret with two of crude tartar, and throw the mixture by spoonfuls into a red-hot crucible; then heat the mass to redness, and a button will be found at the bottom of the crucible, which is the metal as it commonly occurs in commerce, and is nearly pure. Reduce this button to fine powder, and dissolve it in nitro-muriatic acid;

pour this solution into water, which will occasion the precipitation of a white powder, which is to be washed and mixed with twice its weight of tartar and exposed to a dull red heat in a crucible. The button now obtained is pure antimony.

906. Antimony is of a silvery white colour, brittle, and crystalline in its ordinary texture. It fuses at about 800°, and is volatile at a high heat. Its specific gravity is 6.712. (Hatchett, *Phil. Trans.*, 1803.) Placed upon ignited charcoal, under a current of oxygen gas, antimony burns with great brilliancy, throwing off its oxide in the form of a dense yellow smoke.

907. *Antimony and Oxygen.*—These bodies form two well-defined compounds, the history of which is of great importance to the pharmaceutical chemist.

The *Protoxide of Antimony* is thus obtained: To 200 parts of sulphuric acid add 50 parts of powdered metallic antimony. Boil the mixture to dryness, wash the dry mass, first in water, and then with a weak solution of carbonate of potassa; a white powder remains, which, when thoroughly washed with hot water, is *Protoxide of Antimony.* It may also be procured by dissolving antimony in muriatic acid, pouring the solution into water, and washing the white precipitate with weak solution of potassa.

908. This oxide may also be obtained by adding ammonia to solution of tartrate of antimony and potassa, heating the mixture, and washing the precipitate in large quantities of boiling water. It is thus procured in the form of a heavy white powder. This process is directed in the *Pharmacopœia.*

This protoxide exists in all the active antimonial preparations; in emetic tartar, kermes, glass of antimony golden sulphuret, *&c.* It is fusible and volatile at a red heat: decomposed by sulphur and charcoal; and when acted on by nitric acid, is converted into peroxide. If heated with chlorate of potassa it deflagrates and also becomes peroxidized; it is very soluble in muriatic acid, and readily forms emetic tartar when boiled in solution of tartrate of potassa.

When metallic antimony in fusion is exposed to a bright red heat, it is converted into an oxide which appears to be the protoxide, and which condenses in long and delicate needles when sublimed. It was formerly called *argentine flowers of antimony.*

909. *Peroxide of Antimony* is procured by acting for a considerable time upon the powdered metal, by excess of hot nitric acid, and exposing the product to a red heat. The *diaphoretic antimony* and *Bezoar mineral* of old *Pharmacopœiæ* consisted of this oxide, which compared with the protoxide is nearly inert.

910. Peroxide of antimony is also formed by exposing the metal or the protoxide mixed with five or six parts of nitre to a red heat, in a porcelain crucible, and washing the residue with hot water. It is yellowish white, but becomes buff-coloured when heated, and returns to its former tint on cooling. It neither fuses nor volatilizes at a bright red heat, but when exposed to the flame of a spirit-lamp urged by a blowpipe, it passes off slowly in white fumes, being partially reduced by the hydrogen of the flame.

911. Berzelius (*Ann. de Chim.*, lxxxvi. 225), has described four oxides of antimony; but it is probable

that the first and the fourth are not distinct compounds: they are said to be constituted as follows:

1 Suboxide consisting of	100 antimony	+ 4.65 oxygen.
2 Oxidule	100	+18.60 ......
3 White oxide	100	+27.90 ......
4 Yellow oxide	100	+37.20 ......

The two last oxides are called by Berzelius, *stibious* and *stibic* acids, or *antimonious* and *antimonic* acids.

The second and fourth are probably the oxides described in paragraphs 908 and 909, but their composition is by no means satisfactorily ascertained.

912. *Native Oxide of Antimony* is occasionally found incrusting the native metal and the sulphuret.

913. I have found by experiment that the oxygen in the protoxide (908) is to that in the peroxide (909) as 1 to 2; and if we consider these as the second and fourth oxide described by Berzelius, we obtain the number 40 as the representative of antimony. Dr. John Davy's researches on the composition of the chlorides, (*Phil. Trans.*, 1812,) give the number 42.5 as the representative of antimony; and this nearly agrees with my own experiments upon the composition of the protoxide, (obtained by precipitation from emetic tartar), which give 45, and which I shall therefore adopt.

The protoxide of antimony will then consist of

$$\text{Antimony } 45 + \text{Oxygen } 7.5 = 52.5.$$

And the peroxide will be composed of

$$\text{Antimony } 45 + \text{Oxygen } 15 = 60.$$

914. The acid properties of peroxide of antimony were long since remarked by Thenard, (*Ann. de Chim.*, xxxviii. and xli.) and the subject has lately been investigated by Berzelius, who obtained it by exposing a mixture of one part of powdered antimony and six of nitre to a red heat in a silver crucible for an hour. After washing off the soluble matters by cold water, and digesting the white powder which remains in muriatic acid, washing and drying it at a red heat, it is pure *antimonic acid*, and consists of antimony 100, oxygen 37.2.

915. *Antimoniate of Ammonia* is formed by digesting the acid in ammonia. On evaporation a *superantimoniate of ammonia* is obtained in the form of a white powder.

916. *Antimoniate of Potassa* is contained in the white powder obtained by igniting nitre and antimony. (919). It dissolves in hot water, and this solution produces precipitates of insoluble antimoniates in several other metallic solutions.

Our knowledge of the composition and properties of the oxides of antimony, and of most of their combinations, is still extremely imperfect, and the whole subject requires further investigation before the anomalies that now present themselves can be cleared up.

917. *Antimony and Chlorine* combine in one proportion only to produce the *chloride of antimony*. The powdered metal takes fire when thrown into the gas, and a compound, at first liquid, but afterwards concreting, is formed. It may also be produced by the distillation of one part of powdered antimony with two and a half of bi-chloride of mercury; or by dis-

solving the protoxide of antimony in muriatic acid, and evaporating to dryness. It consists of 45 A. + 33.5 C. The pure chloride is a soft solid at common temperatures, but becomes liquid by a gentle heat, and crystallizes as it cools. It is the *butter of antimony* of old writers. It deliquesces by exposure to air; and is a powerful caustic. When water is added to the chloride of antimony, a mutual decomposition ensues, and hydrated protoxide of antimony, formerly called *Algarotti's powder*, or *mercurius vitæ,* and muriatic acid result.

918. *Chlorate of Antimony* has not been examined.

919. *Iodide of Antimony* is of a dark red colour; acted upon by water, it produces hydriodic acid and oxide of antimony.

920. *Iodate of Antimony* is unknown.

921. Nitric acid acts powerfully on metallic antimony, and if mixed with it in fine powder, will sometimes cause its inflammation. The metal becomes peroxidized, and scarcely an appretiable portion is retained in solution. As in some other cases of the vehement decomposition of nitric acid, ammonia is produced, (287) which may be rendered sensible by pouring potassa on the white magma that results.

Protoxide of antimony, digested in dilute nitric acid, produces a difficultly soluble salt, which separates in white scaly crystals, and which appears to be a *nitrate of antimony*, but I have not particularly examined it.

922. Nitro-muriatic acid readily dissolves antimony, and forms an orange-coloured solution, which is decomposed by the addition of water. Iron or zinc immersed into this solution throws down a black powder, which, according to Thenard, is pyrophoric.

923. *Sulphuret of Antimony* is easily formed by fusing the metal with sulphur. It consists of 45 A. + 15 S. Its colour is dark grey and metallic. Its sp. gr. 4.36. It closely resembles the native sulphuret (905.)

924. When the native sulphuret is exposed under a muffle to a dull red heat, it gradually loses sulphur and absorbs oxygen, being converted into a grey powder, which consists of a mixture of protoxide of antimony and sulphuret. If the heat be increased, this fuses into a transparent substance of a yellow or brown colour, formerly called *glass of antimony*. Its composition is variable; it generally contains about 85 *per cent.* of protoxide and 15 of sulphuret. In that which is imported for pharmaceutical purposes, from Germany and Holland, there is usually a portion of siliceous earth, and it is sometimes adulterated with oxide of lead. This fraud is easily detected by digesting the finely-powdered glass in hot nitric acid, diluting the solution and filtering. The filtered liquor gives a white precipitate on the addition of sulphate of soda, if lead were present.

During the formation of glass of antimony, if the heat be raised too high the greater part of the protoxide sublimes in slender crystalline needles; while another portion, if air be not excluded, passes into the state of peroxide, and undergoes no change at a very high temperature.

Compounds of the protoxide with larger quantities of the sulphuret have been termed *saffron of antimony* or *crocus metallorum*, and *liver of antimony*.

925. Neither the *Hyposulphite* nor the *Sulphite* of antimony are known.

926. *Sulphate of Antimony.*—When sulphuric acid

is boiled upon finely-powdered antimony, the metal is oxidized, and an acid *sulphate* and a *subsulphate of antimony* are the results. In both these salts the metal is in a state of protoxide. (907.)

927. *Hydrosulphuretted Oxide of Antimony.*—This compound has long been known under the name of *kermes mineral;* it is commonly prepared as follows: Equal parts of sulphuret of antimony and common potash are fused together; the resulting mass is finely powdered, and boiled in ten times its weight of water. The liquor is filtered while hot; and, during cooling, it deposits *kermes.* The mother liquor of kermes deposits a copious yellowish red precipitate upon the addition of dilute sulphuric acid, which, when washed and dried, is known under the name of *golden sulphur of antimony.* In the *London Pharmacopœia* it is called *antimonii sulphuretum præcipitatum.*

In forming these compounds, the following changes seem to have taken place. The sulphuret of antimony and potassa acts upon the water, a portion of which is decomposed; hydrogen is transferred to the alcaline sulphuret, to form hydrosulphuret of potassa; hydrogen and oxygen unite to the sulphuret of antimony, producing a hydrosulphuretted oxide of that metal (*kermes*), which remains dissolved in the hot alcaline hydrosulphuret, and of which one portion is precipitated as that solution cools. When dilute sulphuric acid is added, the hydrosulphuret of potassa is decomposed, sulphate of potassa is formed, and sulphur and sulphuretted hydrogen are liberated; the sulphur falls in combination with the *kermes,* producing the *golden sulphur,* or sulphuretted hydrosulphuret.

928. *Phosphuret of Antimony* is formed by heating together equal parts of oxide of antimony, phosphoric acid, and charcoal. It is white and brittle.

929. Nothing is known respecting either the *Hypophosphite* or the *Phosphite* of antimony.

930. *Phosphate of Antimony* has not been formed: in the *London Pharmacopœia* there is a preparation called *pulvis antimonialis,* formed by heating one part of sulphuret of antimony with two of hartshorn shavings. The action of heat upon the sulphuret has already been described. (924.) Its effect upon the hartshorn shavings is to destroy the animal matter, leaving little else than phosphate of lime. So that the *pulvis antimonialis* consists essentially of protoxide of antimony, mixed with phosphate of lime. This preparation is usually considered analogous to, if not identical with, *James's Powder,* which, according to Dr. Pearson's analysis (*Phil. Trans.*, 1791), consists of 43 phosphate of lime, and 57 oxide of antimony.

931. In examining Antimonial Powder from various sources, prepared according to the direction of the *Pharmacopœia,* I have found it of very variable composition: sometimes it contains peroxide of antimony only; sometimes there is a proportion of protoxide, and in some few cases the powder has consisted chiefly of bone-earth. These differences are referable to the mode of preparing it, but in almost every case, a very large proportion of the protoxide is lost during the process, and I have found it a matter of great difficulty so to conduct it as to obtain, upon the large scale, an uniform product. For medical use I should consider emetic tartar as the only certain and necessary preparation of antimony; if,

however, a compound of the nature of the Antimonial Powder be requisite, one of the best modes of preparing it would be to dissolve certain proportions of protoxide of antimony and phosphate of lime in muriatic acid, precipitate by ammonia, and edulcorate with a large quantity of water. Mr. Chenevix advises for this purpose equal parts of the oxide and phosphate, but such proportion of antimony is too great: I have made an useful Antimonial Powder by dissolving 200 grains of bone-earth and 100 of protoxide of antimony in a measured ounce and a half of muriatic acid, and pouring the solution into a weak solution of ammonia; the precipitate, when washed, dried, and reduced to a fine powder, weighed 280 grains.

932. The following method furnishes, in the dry way, a tolerably uniform Antimonial Powder: Burn two pounds of hartshorn to a cinder, reduce it to powder, and heat it to a dull redness in an iron pot: then gradually stir into it one pound of powdered sulphuret of antimony, added in successive portions, and continue the same heat as long as fumes arise; when these cease the mixture will have a dirty grey colour, and during the operation small crystals of protoxide of antimony will be seen to collect upon its surface when a portion is taken out in an iron spoon. In this grey state it should be put into a crucible and heated to intense redness; a phosphorescent light of a greenish tint is soon perceived, and when this ceases the crucible may be removed from the fire, and its contents when cold reduced to a fine powder, which should be perfectly white.

933. Neither *carbonate*, *hydrocyanate*, nor *borate* of antimony are known to exist.

934. The solutions of antimony afford orange-coloured precipitates with sulphuretted hydrogen, and those which are acid are precipitated when largely diluted with water.

935. Antimony forms brittle alloys with the malleable metals. When gold was alloyed with $\frac{1}{1920}$ its weight of antimony, the compound was perfectly brittle; and even the fumes of antimony in the vicinity of melted gold are sufficient to destroy its ductility. (Hatchett, *Phil. Trans.*, 1803). With potassium and sodium it forms white brittle compounds, destructible by the action of air and water.

Its alloys with manganese and with zinc have not been examined.

Alloyed with lead in the proportion of 1 to 16, and a small addition of copper, antimony forms the alloy used for *printers' types.* With lead only, a white and rather brittle compound is formed, used for the plates upon which music is engraved. With iron it forms a hard whitish alloy formerly called *martial regulus,* which may be obtained by fusing two parts of sulphuret of antimony with one of iron filings; a scoria consisting chiefly of sulphuret of iron is formed, and the fused alloy beneath usually presents a stellated appearance in consequence of its crystallization. This star was much admired by the alchymists, who considered it a mysterious guide to transmutation. With tin antimony constitutes a kind of *pewter,* a term however which has also been applied to some other alloys, especially that of lead and tin. (902.) The finest pewter consists of about 12 parts of tin and 1 of antimony, with a small addition of copper. A good white metal, used for teapots, is composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper.

936. The analysis of an alloy of tin, lead, copper, and antimony, may be thus performed: Introduce 100 grains into a matrass with a wide mouth, and pour upon it one ounce of water and two of nitric acid ; digest and evaporate to dryness. The dry mass will consist of the nitrates of lead and copper, which are soluble, and may be taken up by two ounces of hot water, and of the peroxides of tin and antimony, which are insoluble, and remain upon the filter.

To the solution of the nitrates add sulphate of soda, which throws down sulphate of lead, and which is to be collected in a filter, washed, dried at a red heat, and weighed. (888.) The filtered liquor may be evaporated to about two ounces in bulk, and having rendered it slightly acid by dilute sulphuric acid, immerse in it a plate of iron, which will throw down metallic copper, to be purified if requisite (820), dried, and weighed.

The separation of the peroxides of tin and antimony is attended with many difficulties: it may be imperfectly effected by solution in nitromuriatic acid, and subsequent dilution with a large quantity of water, which throws down the antimonial oxide, not however pure, but with a portion of peroxide of tin: the latter, retaining a little peroxide of antimony, may be procured by evaporation and exposure of the residue to a dull red heat in a porcelain cup.

SECTION XVI. *Bismuth.*

937. THIS metal is found native; combined with oxygen; and with arsenic and sulphur.

Native Bismuth occurs crystallized in octoëdra and cubes, and generally contains arsenic and sometimes cobalt. It has been found in Cornwall, and in Germany, France, and Sweden.

938. The metal may be obtained pure, by dissolving the bismuth of commerce in nitric acid; water is added to the nitric solution, which separates oxide of bismuth. This oxide is easily reduced in the usual way.

Bismuth is a brittle white metal, with a slight tint of red: its specific gravity is 9.822. (HATCHETT, *Phil. Trans.*, 1803.) It fuses at 476°, and always crystallizes on cooling.

939. When bismuth is exposed to heat and air it oxidizes, forming a fusible *white oxide.* If the heat be increased by directing a current of oxygen upon the metal, it burns with much brilliancy, and produces an abundant yellow smoke, which condenses in the form of a yellowish white sublimate. When in fusion this oxide acts upon other oxides much in the same way as oxide of lead. It consists of 66.5 bismuth + 7.5 oxygen. It occurs, though very rarely, *native:* it has been found in Cornwall and Saxony.

940. *Chloride of Bismuth,* is procured by heating

the metal in the gas, or by evaporating the muriate to dryness and submitting the residue to distillation, when the chloride sublimes, and afterwards deliquesces into what was called *butter of bismuth.* (J. DAVY, *Phil. Trans.*, 1812.) It consists of 66.5 bismuth + 33.5 chlorine.

941. *Chlorate of Bismuth* has not been examined.

942. *Iodide of Bismuth,* obtained by heating iodine with the metal, is of an orange-colour, and insoluble in water. When hydriodic acid or hydriodate of potassa is added to nitrate of bismuth, a precipitate falls of a deep chocolate-brown colour, insoluble in water, but soluble in liquid potassa.

943. *Iodate of Bismuth* is thrown down upon adding iodate of potassa to nitrate of bismuth.

944. *Nitrate of Bismuth.*—This salt crystallizes in small four-sided prisms, consisting of 74 oxide + 50.5 acid. It is made by dissolving the metal to saturation in two parts of nitric acid and one of water: the action is rapid, and nitric oxide is copiously evolved. Ammonia occasions a precipitate in nitrate of bismuth, which is re-dissolved by excess of the alcali. Potassa and soda also throw down the oxide, which is but sparingly soluble in those alcalis.

945. Nitrate of Bismuth is decomposed by water, and the oxide of bismuth is thrown down in the form of a fine white powder, called *magistery of bismuth, pearl white,* or *blanc de fard.* In this state it has been used in medicine as a tonic.—*Quarterly Journal,* viii. 295.

946. If characters be written on paper with nitrate of bismuth they are invisible when dry, but

become white and legible on immersion in water, thus forming a *white sympathetic ink.* The same characters are rendered brown or black by solution of sulphuretted hydrogen.

947. *Sulphuret of Bismuth* is of a bluish colour and metallic lustre; it consists of 66.5 B. + 15 sulphur. (J. Davy, *Phil. Trans.*, 1812.) The compound analyzed by Vauquelin appears to have been a *bi-sulphuret.* —*Annales du Museum*, Tom. xv.

948. *Native Sulphuret of Bismuth* has been found in Cornwall, Bohemia, Saxony, and Sweden. It occurs massive and acicular, its lustre is metallic, and its colour bluish grey. It is a very rare mineral.

949. Neither the *Sulphite* nor the *Hyposulphite of Bismuth* have been examined.

950. *Sulphate of Bismuth* consists of 74 oxide + 37.5 acid; it is a white compound, insoluble in, but decomposed by, water, which converts it into a *subsulphate* and *supersulphate.*

951. *Hydrosulphuretted Oxide of Bismuth* is of a deep brown approaching to black. It is thrown down from nitrate of bismuth by sulphuretted hydrogen.

952. *Phosphuret of Bismuth* does not, according to Pelletier, exist; at least, it cannot be formed by the usual process.

953. Neither the *hypophospite, phosphite, phosphate, carbonate, ferrocyanate*, nor *borate* of bismuth have been sufficiently examined.

954. Bismuth forms *alloys,* some of which are remarkable for their fusibility. With gold, platinum, and silver, it forms brittle compounds. A compound of eight parts of bismuth, five of lead, and three of

tin, liquefies at 212°; it is called Sir. I. Newton's *fusible metal.* The addition of one part of quicksilver renders it yet more fusible. Bismuth enters into the composition of *soft solders.* These alloys are mostly white, brittle, and easily oxydated.

SECTION XVII. *Cobalt.*

955. THE native combinations of cobalt are the oxide, and compounds of the metal with iron, nickel, arsenic, and sulphur. It is also found combined with arsenic acid. In the white and grey cobalt ores, the metal is combined with iron, and with arsenic: Some of the varieties are crystallized in cubes, octoëdrons and dodecaëdrons. The red ore is an arseniate. The finest specimens are the produce of Saxony.

956. To obtain pure cobalt, the cobalt of commerce, in fine powder, may be calcined with four parts of nitre, and washed in hot water, by which arsenic is separated: then digest in dilute nitric acid, and immerse a plate of iron, which will separate the copper; filter and evaporate to dryness; digest the dry mass in liquid ammonia and filter; expel the excess of ammonia from the filtered liquor by heat, taking care not to produce a precipitate, and then add solution of potassa, which throws down oxide of nickel; filter immediately, and boil, which will occasion the separation of oxide of

cobalt, and which, ignited with charcoal, furnishes the pure metal. In this process the first calcination with nitre often requires two or three repetitions in order to get rid of the whole of the arsenic, which adheres to cobalt with much obstinacy.

957. Cobalt is of a reddish grey colour, brittle, and difficultly fusible. Its specific gravity is 7.7. It is magnetic.

958. *Cobalt and Oxygen* unite in two proportions. The *protoxide* is formed by adding potassa to the nitrate, and drying the precipitate; it appears very dark blue or nearly black. By exposure to heat and air it absorbs an additional portion of oxygen, and is thus converted into black *peroxide.* The protoxide, when recently precipitated and moist, is *blue;* and, if left in contact of water, becomes a *red hydrate.* The composition of the protoxide of cobalt, deduced from the analysis of the chloride (960) is 30.5 cobalt + 7.5 oxygen = 38.; or 100 cobalt + 24.7 oxygen.

This result is nearly the mean of those published by Proust, (*Annales de Chimie*, Vol. lx.) and Rothoff, (*Annals of Phil.* Vol. iii.) It appears from the experiments of the latter chemist, that the peroxide of cobalt contains 100 metal + 36.7 oxygen, which, in reference to the above deduction from the chloride, would lead us to consider it as containing one proportional of cobalt and one and a half of oxygen. All the salts of cobalt contain the protoxide.

959. Cobalt burns when heated in chlorine; and forms *chloride of cobalt.* When muriate of cobalt is evaporated to dryness, and the residuum heated to redness out of the contact of air, a substance of a blue

colour and micaceous texture is obtained, which is a pure chloride of cobalt. It dissolves perfectly in water, forming a pink solution.

960. As the chloride of cobalt is easily formed, and as it is a perfectly definite compound, it offers an unexceptionable substance, from which, by analysis, to deduce the equivalent number of the metal. For this purpose 32 grains of the pure chloride were dissolved in water, and decomposed by solution of nitrate of silver: the precipitate of chloride of silver, dried at a dull red heat, weighed 68 grains, which is the equivalent of 16.73 grains of chlorine; hence the 32 grains of chloride of cobalt are composed of 16.73 chlorine + 15.27 cobalt; and 16.73 : 15.27 :: 33.5 : 30.51 = the equivalent of cobalt. The chloride of cobalt, therefore, may be considered as composed of

1 proportional of cobalt.... = 30.50
1 ———————— chlorine .. = 33.50
64.

961. *Chlorate of Cobalt* has not been examined.

962. *Muriate of Cobalt* is a deliquescent salt, of a blue green colour; it may be formed by digesting either oxide in muriatic acid; if the peroxide be used, chlorine is evolved, and it passes to the state of protoxide. When a little diluted, this solution becomes pink; the pale pink solution, when written with, is scarcely visible; but if gently heated, the writing appears in brilliant green, which soon vanishes as the paper cools, in consequence of the salt absorbing the aërial moisture. This solution has been termed *Hellot's sympathetic ink.*

963. *Iodide* and *Iodate of Cobalt* remain unexamined. No precipitate is produced in muriate of cobalt either by hydriodic acid or hydriodate of potassa.

964. With nitric acid the oxide of cobalt furnishes a red deliquescent *nitrate of cobalt.*

965. Ammonia digested upon recently precipitated protoxide of cobalt slowly dissolves it, and forms a pale pink solution, which becomes deeper coloured by exposure to air, in consequence of the metal passing to the state of peroxide. The ammoniacal solution of the peroxide forms acicular crystals of a beautiful pink colour.

966. *Sulphuret of Cobalt* is formed by heating the oxide with sulphur. It is yellowish white.

967. Neither the *Sulphite* nor the *Hyposulphite of Cobalt* have been examined.

968. *Sulphate of Cobalt* forms red rhombic crystals, soluble in 24 parts of water at 60°. It may be made by dissolving the newly precipitated protoxide in sulphuric acid diluted with its bulk of water. In its crystallized state it consists of one proportional of oxide, one of acid, and seven of water; or

38	protoxide of cobalt
37.5	sulphuric acid
59.5	water
147.5	

When dried at a temperature of 500°, the crystals fall into a blue powder, which in a bright red heat fuses and gives out sulphuric acid, leaving a black oxide. The blue powder is the *anhydrous sulphate of cobalt,* perfectly soluble in water, and forming a pink solution; it is slightly deliquescent, and becomes lilac-coloured by exposure to air.

969. Fifty grains of dry sulphate of cobalt dissolved in water, furnished a precipitate with muriate of baryta, amounting, when dried at a red heat, to 75 grains of sulphate of baryta, which is the equivalent of 25.5 grains of sulphuric acid: this method of analysis, therefore, shows that sulphate of cobalt consists very nearly of equal weights of sulphuric acid and protoxide of cobalt, and may be considered as verifying the analysis of the chloride. (960.)

970. Sulphate of cobalt forms triple compounds with potassa and with ammonia, which have not been examined. If it contain nickel, the crystals are of a greenish tinge, but pink when the cobalt is pure.

971. *Hydrosulphuretted Oxide of Cobalt* is precipitated from the muriate by hydrosulphuret of ammonia, of a black colour.

972. *Phosphuret of Cobalt* is a white brittle compound.

973. Nothing is known respecting the *Hypophosphite* and *Phosphite of Cobalt.*

974. *Phosphate of Cobalt* may be formed by double decomposition, as by adding phosphate of soda to muriate of cobalt; it is insoluble, of a lilac colour, and if mixed with eight parts of gelatinous alumina and heated, it produces a beautiful blue, which may sometimes be employed by painters as a substitute for ultramarine. (THENARD, Tom. ii. p. 419.) The theoretical composition of phosphate of cobalt is 38 oxide + 26 acid.

975. *Carbonate of Cobalt* is formed by decomposing the nitrate, muriate, or sulphate of cobalt by carbonate of potassa, or soda ; a reddish blue powder is precipitated.

976. Ferrocyanate of potassa forms a grass-green precipitate in solutions of cobalt.

977. Solution of borax produces a pink precipitate in solution of muriate of cobalt, which is probably a *borate of cobalt.*

978. The salts of cobalt all contain the protoxide ; they are decomposed by ammonia, which, if added in excess, re-dissolves the oxide : phosphoric, carbonic, arsenic, and oxalic acids, produce, by double decomposition, insoluble red or lilac precipitates in these solutions.

979. The alloys of cobalt are unimportant.

980. The chief use of cobalt is as a colouring material for porcelain, earthenware, and glass ; it is principally imported from Germany in the state of *zaffre,* and *smalt* or *azure.*

Zaffre is prepared by calcining the ores of cobalt, by which sulphur and arsenic are volatilized, and an impure oxide of cobalt remains, which is mixed with about twice its weight of finely-powdered flints.

Smalt and *azure blue* are made by fusing zaffre with glass ; or by calcining a mixture of equal parts of roasted cobalt ore, common potash, and ground flints. In this way a blue glass is formed, which, while hot, is dropped into water, and afterwards reduced to a very fine powder.

Section XVIII. *Uranium.*

981. The *native hydrated oxide* of this metal has been termed *uranite,* or *uranitic mica.* Its crystalline form is the cube, and several modifications; it often occurs in thin quadrangular plates. It exhibits various shades of yellow and green. It has been found in France; and of great beauty near Callington, in Cornwall.

982. The *native sulphuret of uranium* was formerly mistaken for an ore of zinc, and called *pechblende,* till Klaproth, in 1789, demonstrated it to contain uranium combined with sulphur. From this ore uranium may be obtained by the following process: Reduce it to powder, and expose it to heat in a muffle; then digest in dilute nitro-muriatic acid, and precipitate by excess of ammonia, to retain oxide of copper; collect and wash the precipitate, and dry it at a heat approaching redness.

When exposed to a violent heat with a small quantity of charcoal powder, metallic uranium is obtained.

Uranium is of a grey colour, brittle, and very difficult of fusion; its specific gravity has not been ascertained with precision. Bucholz states it as = 9.0.—Gehlen's *Journal,* iv.

983. Very few experiments have hitherto been made upon this metal. The oxide precipitated from its nitric solution by alcalis is yellow, but by heating with charcoal it becomes black.

984. *Chloride, Muriate,* and *Chlorate of Uranium*

have not been examined; nor is any thing known of the *Iodide* or *Iodate of Uranium.*

985. *Nitrate of Uranium,* formed by digesting the peroxide in dilute nitric acid, and crystallizing, forms yellow prismatic crystals, easily soluble, deliquescent in a moist air, and containing, according to Bucholz,

61	oxide
25	acid
14	water
100	

986. *Subnitrate of Uranium,* upon the authority of Bucholz, is formed by heating the nitrate, which renders a part insoluble in water, and separates in the form of a yellow powder.

987. *Sulphuret of Uranium* exists native. Neither the *Hyposulphite* nor *Sulphite of Uranium* have been examined.

Sulphate of Uranium forms yellow prismatic crystals, decomposable by heat, and, according to the analysis of Bucholz, consisting of

70	oxide
18	acid
12	water
100	

988. According to the same authority, the peroxide of uranium consists of 80 metal + 20 oxygen = 100; so that if we consider it as containing one proportional of metal and two of oxygen, we obtain 60 as the representative number of uranium; and as it is probable that the protoxide contains half the quantity

of oxygen, the oxides would consist respectively of 60 uranium + 7.5 oxygen, and 60 uranium + 15 oxygen; but these numbers are at variance with those derived from the analysis of the salts by the same author, and at all events are merely theoretical.

989. The salts of uranium have a yellow colour and an astringent metallic taste. Potassa forms in their solutions a yellow precipitate, and carbonate of potassa a white precipitate; both these precipitates are insoluble in excess of pure alcali, but dissolve in the carbonate. Ferrocyanate of potassa produces a rich brown precipitate in solutions of uranium, which is very characteristic.

SECTION XIX. *Titanium.*

990. TITANIUM exists in the state of oxide in two minerals, in titanite and in menachanite.

Titanite is a nearly pure oxide of titanium; it is of a brown colour, and occurs embedded in the quartz and granite of primitive countries, and sometimes traverses rock crystals in fine hair-like filaments. In this country it occurs at Bedgellert, in Caernarvonshire; and near Killin, in Scotland. The finest specimens are those from the vicinity of Mont Blanc and St. Gothard.

The mineral, known by the name of *anatase, octoëdrite*, and *oysanite*, is nearly of the same nature as titanite. It is found in Bavaria, Norway, Switzerland, and in the valley of Oysans in France.

Menachanite consists principally of oxides of titanium and iron; it is found in the bed of a small stream at Menachan, in Cornwall. *Nigrine, iserine, rutilite,* and *sphene,* are also ores of titanium.

991. The metal may be obtained from titanite by fusion with potassa; the fused mass, washed with water, leaves oxide of titanium, containing a little iron; it is to be dissolved in muriatic acid, and precipitated by oxalic acid. The oxalate affords the metal by intense ignition with charcoal: it is, however, scarcely possible to obtain it in any state of agglutination: in some trials made in the Royal Institution, nothing like globules of the metal could be procured; and the crucibles were always fused.

992. From menachanite, white oxide of titanium may be obtained by fusing it with potassa, and adding muriatic acid to the alcaline solution.

993. Titanium is of the colour of copper. It is said to be susceptible of three degrees of oxidizement, the colours of the oxides being blue, red, and white.

The *blue* is formed by exposing the metal to heat and air; the *red* is the native oxide; and the *white* is that which is precipitated from the alcaline solution of titanite and menachanite by muriatic acid. According to Vauquelin and Hecht, (*Journal des Mines,* No. xv.) the white oxide contains 89 parts of red oxide and 11 of oxygen.

994. The action of chlorine, of iodine, and of their acids, upon titanium, have not been examined. The *carbonate of titanium* dissolves in muriatic, nitric, and sulphuric acids, and phosphoric acid occasions a white precipitate in these solutions. Neither the *muriate,*

nitrate, nor *sulphate*, are crystallizable. The solution of the muriate is speedily decomposed by exposure to light, and a white precipitate of oxide is formed in it.

995. When the native oxides of titanium are fused with carbonate of potassa, at a temperature not too high, a white *carbonate of titanium* is formed.

996. The solutions of titanium are colourless, and afford white precipitates with the alcalis; ferrocyanate of potassa gives a green precipitate, and infusion of galls a red one. Hydrosulphuret of ammonia occasions a greenish precipitate.

SECTION XX. *Cerium.*

997. THIS metal was obtained by Hisinger and Berzelius, from a mineral found at Bastnas in Sweden, to which they have given the name of *cerite*. It is also contained in *Allanite*, a mineral from Greenland, first distinguished as a peculiar species by Mr. Thomas Allan, of Edinburgh. It contains, according to Dr. Thomson's analysis, about 40 *per cent.* of oxide of cerium.

The ore is calcined, pulverized, and digested in nitro-muriatic acid. To the filtered solution saturated with potassa, oxalic acid is added, which occasions a precipitate; this, when dried and ignited, is oxide of cerium.

This oxide is extremely difficult of reduction. Mr. Children succeeded in fusing it by the aid of his powerful Voltaic apparatus, and when intensely heated it burned with a vivid flame, and was partly volatilized. Vauquelin describes cerium as a hard white brittle metal.—*Annales de Chimie,* Vol. iv.

998. Vauquelin and Hisinger have described two *oxides of cerium.* The *protoxide* is white, and consists of cerium 100 + oxygen 17.41. The *peroxide* is brown, and contains cerium 100 + oxygen 26.11. If we regard the first oxide as containing 1 proportional of metal + 2 of oxygen, and the second, 1 + 3, then the number representing cerium will be 86.2, and the oxides will consist respectively of 86.2 cerium + 15 oxygen, and 86.2 cerium + 22.5 oxygen.

999. Muriatic and sulphuric acids dissolve the red peroxide of cerium: the solutions afford yellow crystals. The muriate is deliquescent; the sulphate difficultly soluble. The sulphate of the protoxide forms white crystals of a sweet taste. Nitric acid forms with the protoxide a deliquescent compound, of a sweet taste. The carbonate is precipitated from these solutions in the form of a white powder.

1000. The salts of cerium are either white or yellow, as they contain either the protoxide or peroxide. Their neutral solutions taste sweet. Ferrocyanate of potassa, and oxalate of ammonia, produce white precipitates soluble in nitric and muriatic acids. Neither sulphuretted hydrogen, nor gallic acid, occasion any precipitate.

SECTION XXI. *Tellurium.*

1001. THE ores of tellurium are, 1. *Native*, in which the metal is combined with iron and a little gold. 2. *Graphic ore*, which consists of tellurium, gold, and silver. 3. *Yellow ore*, a compound of tellurium, gold, lead, and silver; and 4. *Black ore*, consisting of the same metals with copper and sulphur.

These ores have only been found in the Transylvanian mines, and in Siberia.

The metal is extracted from them by precipitating their diluted nitro-muriatic solution by potassa, which is added in excess: the clear liquor is poured off and saturated with muriatic acid, which affords a precipitate of oxide of tellurium. This, heated in a glass retort with charcoal, furnishes the metal. Tellurium is of a bright grey colour, brittle, easily fusible, and very volatile. Its specific gravity is 6.1.

1002. *Oxide of Tellurium.*—Exposed to heat and air, tellurium readily burns, exhaling a peculiar odour, and forming a yellowish white oxide, consisting, according to Klaproth, (*Beiträge*, Vol. iii.) of

Tellurium	100
Oxygen	20.5

Hence the number 36.5 may be adopted as the representative of the metal; and if the above be considered a protoxide, it will contain

1 proportional of tellurium	=	36.5
1 ———— of oxygen	=	7.5
Oxide of tellurium	=	44

1003. *Chloride of Tellurium* is a white fusible compound, formed by heating the metal in chlorine. According to Davy, (*Elements*, p. 410.) it consists of 2 tellurium + 1.85 chlorine, which would give 1 proportional of each of its components, or

Tellurium	36.5
Chlorine	33.5
Chloride of tellurium	70

The *Chlorate of Tellurium* is not known.

1004. Iodine readily combines with tellurium, forming a deep brown *iodide*, which dissolves in water, forming the *hydriodate of tellurium*. The *Iodate of Tellurium* has not been examined.

1005. The salts of tellurium are decomposed by the alcalis, and the precipitate is re-dissolved when they are added in excess. Hydrosulphuret of ammonia forms a brown precipitate; ferrocyanate of potassa occasions no change. Zinc or iron, immersed into the solutions, cause the separation of metallic tellurium.

1006. Tellurium combines with hydrogen, producing *telluretted hydrogen gas*. The soluble salts of tellurium furnish white precipitates when neutralized by alcalis, which are soluble in excess either of the solvent or precipitant.

1007. The oxide of tellurium is readily soluble in muriatic, nitric, and sulphuric acids. The muriate affords a precipitate on the addition of water.—Berzelius, Nicholson's *Journal*, xxxvi.

1008. The oxide of tellurium combines with many of the metallic oxides, acting the part of an acid, and producing a class of compounds which have been called *tellurates*.

1009. *Tellurate of Potassa* may be formed by heating oxide of tellurium with nitre, and dissolving the residuum in boiling water, which, on cooling, deposits an imperfectly crystallized white powder, difficultly soluble in water.

1010. Solution of tellurate of potassa, added to solutions of lime, baryta, strontia, copper, and lead, forms insoluble tellurates of the oxides of those metals.

Section XXII. *Selenium.*

1011. This body is placed, rather from analogy than experiment, among the metals. It was discovered by Berzelius in the sulphur of Fahlun in Sweden, and was first suspected to be tellurium. Its colour is grey; its lustre bright metallic. It fuses at a few degrees above the boiling point of water, and when slowly cooled, assumes a granular fracture. It boils and evaporates in close vessels at a temperature a little below redness. Heated before the blow-pipe it volatilizes with a very powerful and peculiar smell, somewhat like that of horse-radish.

Selenium unites with the metals. With potassium it combines with great energy, producing a greyish compound, with metallic lustre, and which, when thrown into water, evolves *selenuretted hydrogen gas,* which is highly irritating to the nostrils. It combines both in the dry and humid way with the fixed alcalis, and forms red compounds. Heated to dryness with nitric acid it forms a volatile and crystallizable compound, called *selenic acid,* which unites to some of the metallic oxides, producing a distinct class of *seleniates.*—*Annales de Chimie et Physique,* Tom. vii.; THOMSON'S *Annals,* Vol. xi. and xii.

SECTION XXIII. *Arsenic.*

1012. THIS metal may be obtained from the white arsenic of commerce, by mixing it with half its weight of black flux*, and introducing the mixture into a Florence flask, placed in a sand bath, gradually raised to a red heat: a brilliant metallic sublimate of pure arsenic collects in the upper part of the flask. The volatility of white arsenic prevents its easy reduction by charcoal alone; but the potassa in the flux enables

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* This is an extremely useful compound for effecting the reduction of many of the metallic oxides. It consists of charcoal and subcarbonate of potassa, and is best prepared by deflagrating in a crucible a mixture of one part of nitre and two of powdered tartar. The mixture remains in fusion at a red heat, and thus suffers the small globules of reduced metal to coalesce into a button.

it to acquire a temperature sufficient for its perfect reduction.

1013. Arsenic is of a steel blue colour, quite brittle, and of a specific gravity = 8.3. It readily fuses, and in close vessels may be distilled at a temperature of 360°, which is lower than its fusing point. Its vapour has a very strong smell, resembling that of garlic. Heated in the air it easily takes fire, burns with a blue flame, and produces copious white fumes of oxide. Exposed to a moist air it gradually becomes incrusted with a grey powder, which is an imperfect oxide. This metal and all its compounds are virulent poisons.

1014. *Native arsenic* has been found in Saxony, Hanover, France, Bohemia, and Cornwall. It usually occurs in rounded masses, or nodules, of a foliated lamellar texture, in the veins of primitive rocks, and is often associated with silver, cobalt, lead, and nickel ores.

1014. *Arsenic and Oxygen.*—There are two definite compounds of arsenic and oxygen, which are both capable of forming combinations with other metallic oxides. They are sour and soluble in water, and have thence been properly termed *arsenious* and *arsenic acids*.

The arsenious acid, or, as it is commonly called, *white arsenic*, or *white oxide of arsenic*, is the best known, and most commonly occurring compound of this metal; and as cases of poisoning by it are frequent, every person should be well acquainted with its characteristic properties.

1016. Arsenious acid may easily be procured by the combustion of the metal; but as it is formed during certain metallurgic processes, that mode is rarely resorted to. It is abundantly prepared at Joachimsthal in Bohemia, from arsenical cobalt ores, which are roasted in reverberatory furnaces, and the vapours condensed in a long chimney, the contents of which, submitted to a second sublimation, afford the *white arsenic* of commerce.

1017. Arsenious acid is white, semi-transparent, brittle, and of a vitreous fracture. Its specific gravity is 3.7. Its taste is acrid, accompanied by a very nauseous sweetness, and it is virulently poisonous, producing inflammation and gangrene of the stomach and intestines: it also proves fatal when applied to a wound; and as the local injury is in neither case sufficient to cause death, it is probable that an induced affection of the nervous system and of the heart is the cause of the mischief. (BRODIE'S *Observations and Experiments on the Action of Poisons,—Phil. Trans.*, 1812.) To get rid of the poison by producing copious vomiting and purging, and to pursue the usual means for subduing and preventing inflammation, are the principal points of treatment to be adopted in cases where this poison has been taken.—ORFILA, *Traité des Poisons*, Tom. i. p. 123.

1018. By a slow sublimation arsenious acid forms tetraëdral crystals: it is volatile at 380°, and has no smell when perfectly free from metallic arsenic. (Dr. PARIS, *Quarterly Journal of Science and Arts*, Vol. vi.) According to Klaproth, 1000 parts of water at 60° dissolve 2.5 of white arsenic; and 1000 parts of water at 212°, dissolve rather more than 77 parts, and about 30 parts are retained in permanent solution. The solutions taste acrid and nauseous, and redden vegetable blues. 80 parts of alcohol at 60°, dissolve one part of this acid. Its aqueous solution furnishes tetraëdral crystals by slow evaporation.

1019. The composition of the arsenious acid, as estimated by Proust, Thenard, and Thomson (THOMSON'S *System*, Vol. i. p. 295.) furnishes the following mean:

Arsenic.		Oxygen.		Arsenious Acid.
100	+	34	=	134.

If we consider this acid as a compound of one proportional of arsenic and two of oxygen, we obtain the number 44.11 as the representative of arsenic; for

$$34 : 100 :: 15 : 44.11.$$

Without material error, therefore, we may adopt 44 as the representative of this metal, and the arsenious acid will then consist of 44 arsenic + 15 oxygen = 59.

1020. *Native White Arsenic* occurs in prismatic crystals, and in a pulverulent form: it is found in Saxony and Hungary.

1021. The arsenious acid forms a distinct class of salts, called *arsenites*, which have been but little examined.

The *arsenites of ammonia*, *potassa*, and *soda*, are easily soluble and uncrystallizable: they are formed by boiling the acid in the alcaline solutions. Those of *lime*, *baryta*, *strontia*, and *magnesia*, are difficultly soluble, and formed in the same way. Arsenite of potassa is the active ingredient in the *liquor arsenicalis* of the *Pharmacopœia*, and in *Fowler's mineral solution* or *tasteless ague drop*.

Arsenite of ammonia produces a yellow precipitate in nitrate of silver, easily soluble in excess of ammonia.

Arsenite of potassa produces a white precipitate in the white salts of manganese ; a dingy green precipitate in the solutions of iron ; a white precipitate in solutions of zinc and tin. Mixed with a solution of sulphate of copper, a precipitate of a fine apple-green colour falls, called from its discoverer, *Scheele's green*, and is useful as a pigment. In the solutions of lead, antimony, and bismuth, it forms white precipitates : added to nitrate of cobalt it forms a pink precipitate; and bright yellow, with nitrate of uranium. With nitrate of silver it forms a white precipitate, soon becoming yellow, and very soluble in ammonia. All these precipitates are probably *arsenites* of the respective metals, and, heated by a blow-pipe on charcoal, they exhale the smell of arsenic.

Native Arsenite of Lead is found in France, in Spain, and in Siberia.

1022. *Arsenic Acid* is obtained by distilling a mixture of 4 parts of muriatic and 24 of nitric acid off 8 parts of arsenious acid, gradually raising the bottom of the retort to a red heat at the end of the operation. It may also be procured by distilling nitric acid off powdered metallic arsenic.

1023. Arsenic acid is a white substance, of a sour taste ; it is deliquescent and uncrystallizable. Its specific gravity is 3.4. It requires for solution 6 parts of cold and 2 of boiling water ; its solution reddens vegetable blues, and tastes acrid and metallic.

1024. It appears, from the experiments of Proust and Thomson, that the oxygen in the arsenic acid is, to that in the arsenious acid, as 3 to 2 ; hence we may regard it as a compound of 1 proportional of arsenic

= 44, and 3 proportionals of oxygen = 22.5, and its representative number will be 66.5.

1025. The *Arseniates* are produced by the union of this acid with the metallic oxides; and many which are insoluble may be formed by adding arseniate of potassa to their respective solutions.

1026. *Arseniate of Ammonia* is formed by saturating arsenic acid with ammonia; rhomboidal prisms are obtained on evaporation, which, when gently heated, effloresce and evolve ammonia: at a higher temperature water is formed, oxide of arsenic sublimes, and nitrogen is evolved, a circumstance first observed by Scheele.

1027. *Arseniate of Potassa* is deliquescent and uncrystallizable.

1028. *Binarseniate of Potassa* may either be formed by adding excess of arsenic acid to potassa and evaporation; or by heating to redness, in a Florence flask, a mixture of equal parts of nitre and white arsenic; during the latter operation much nitrous gas is evolved, and on dissolving the residue in water, filtering, and evaporating, quadrangular crystals of binarseniate of potassa are obtained. Macquer was the first who thus procured this compound, hence it was termed *Macquer's neutral arsenical salt.* It is not easily decomposed by heat alone, and may be fused and kept red hot without undergoing other change than losing a little acid, but when mixed with about an eighth of charcoal powder and distilled, metallic arsenic rises, and carbonate of potassa, mixed with part of the charcoal, remains in the body of the retort. This salt is used in pharmacy for the cure of agues: it consists of

1 proportional of potassa.... = 45
2 ——————— arsenic acid = 133
178

1029. *Arseniate of Soda* is formed by saturating a solution of carbonate of soda with arsenic acid; on evaporation crystals are obtained, which appear to consist of

1 proportional of soda...... = 29.5
1 ——————— arsenic acid = 66.5
96.

1030. *Arseniate of Lime* is deposited when arsenic acid is dropped into lime-water, or when arseniate of potassa is added to nitrate of lime; it is difficultly soluble in water, and consists, according to Laugier (*Annales de Chimie,* lxxxv. 58.) of

Arsenic acid......	67
Lime.............	33

numbers which do not exactly correspond with 1 proportional of acid + 1 of base.

1031. *Arseniate of Baryta* may be formed by mixing arseniate of potassa with nitrate of baryta; when the acid is not in excess it is insoluble in water. It may be considered as a compound of 1 proportional of acid = 66.5 + 1 of baryta = 72.5.

1032. *Arseniate of Strontia* is formed as the last, and is insoluble.

1033. *Arseniate of Magnesia* is soluble, deliquescent, and uncrystallizable.

1034. *Arseniate of Manganese* is precipitated in the form of a white powder, when arseniate of potassa is added to muriate of manganese.

1035. *Arseniate of Iron.*—Arseniate of ammonia, added to the solutions of protosulphate and persulphate of iron, occasions greenish precipitates of *protarseniate* and *perarseniate* of iron, both of which have been examined by Mr. Chenevix.—*Phil. Trans.*, 1801, pp. 220, 225.

1036. *Arseniate of Zinc* is precipitated in the form of a white insoluble powder when arsenic acid, or an alcaline arseniate is added to sulphate of zinc.

1037. *Arseniate of Tin* is a white insoluble powder, precipitated by adding arseniate of potassa to muriate of tin.

1038. *Arseniate of Copper* is formed by adding an alcaline arseniate to nitrate of copper; it is a blue insoluble powder. The arseniates of copper have been submitted to an elaborate investigation by Mr. Chenevix (*Phil. Trans.*, 1801.); he has described five varieties, as shown in the following table.—Thomson's *System*, ii. 616.

	Acid.	Oxide.	Water.
Variety 1*st*.	1.	3.70	2.50
——— 2*d*.	1.	2.76	1.
——— 3*d*.	1.	1.72	0.70
——— 4*th*.	1.	1.80	0.53
——— 5*th*.	1.	0.88	0.60

Dr. Thomson considers these varieties as reducible to four sub-species, as follow: 1*st*. A subarseniate, composed of 1 atom acid + 3 atoms peroxide. 2*d*. A subarseniate, composed of 1 atom acid + 2 atoms peroxide. *3d.* and *4th.* A neutral arseniate, composed of 1 atom acid + 1 atom peroxide. *5th.* A binarseniate, composed of 2 atoms acid + 1 atom peroxide.

1039. *Arseniate of Antimony.*—Nothing is known respecting the combinations of arsenic acid with either of the oxides of antimony.

1040. *Arseniate of Bismuth* falls as an insoluble white powder on adding arsenic acid to nitrate of bismuth.

1041. *Arseniate of Cobalt* is precipitated of a red colour by the addition of an alcaline arseniate to a soluble salt of cobalt.

1042. *Arseniate of Uranium* is thrown down of a straw colour when arseniate of potassa is added to nitrate of uranium.

1043. Several of the metallic arseniates are found *native;* of these the most important are, 1. The *arseniate of iron,* which occurs in Cornwall, usually in cubic crystals of various shades of green. 2. *Arseniate of copper,* of which there are two principal varieties, the green and blue. The green is found in flattened octoëdra, in hexaëdral tables, and in prisms with dihëdral summits. Sometimes it is massive, or fibrous, and radiated. The blue variety is tetraëdral, octoëdral, and rhombic. These beautiful minerals are almost peculiar to Cornwall. 3. *Arseniate of lead* occurs in small hexaëdral crystals, of a yellow, green, or brown colour, transparent, and of a resinous lustre. It has been found in Cornwall, France, and Spain. 4. *Arseniate of cobalt,* or *peachblossom cobalt ore,* is a rare mineral found in Saxony and Cornwall.

1044. *Arsenic and Chlorine.*—*Chloride of arsenic* is formed by throwing finely-powdered arsenic into chlorine; the metal burns and forms a whitish deliquescent and volatile compound; it may also be obtained by distilling 6 parts of corrosive sublimate with 1 of powdered arsenic; the chloride passes into the receiver in the form of an unctuous fluid, formerly called *butter of arsenic*. Mixed with water, the chloride of arsenic is decomposed, and white oxide or arsenious acid is deposited, muriatic acid being at the same time produced. Hence it may be inferred, that the chlorine is to the arsenic in the same proportion as the oxygen, and, consequently, that it consists of 1 proportional of arsenic + 2 proportionals of chlorine, which, from Dr. Davy's experiments, appears to be the case. Chloride of arsenic, therefore, is composed of

44 arsenic + 67 chlorine = 111 chloride of arsenic.

1045. *Chlorate of Arsenic* has not been examined.

1046. *Iodide of Arsenic*, obtained by heating the metal with excess of iodine, is of a deep red colour, and volatile. When acted upon by water, it produces hydriodic and arsenic acids, whence it appears probable that it contains 1 proportional of arsenic and 3 of iodine.

1047. The action of iodic acid on arsenic has not been examined.

1048. *Arsenic and Hydrogen.—Arsenuretted Hydrogen Gas.*—When arsenic is presented to nascent hydrogen, a portion of the metal combines with the gas. The compound is best obtained by adding a portion of metallic arsenic, or of white arsenic, to the mixture of zinc filings and dilute sulphuric acid, usually employed for the production of hydrogen. (227.) The gas may be collected over water, by which it is not sensibly absorbed.

1049. The specific gravity of this gas is liable to vary according to the mode by which it is procured. I have always found it heaviest when obtained from a mixture of 4 parts of zinc, 1 of arsenic, and 3 of sulphuric acid, diluted with 4 or 5 of water. After standing a day over water, it deposits a small quantity of brown matter, which appears to be a *hydruret of arsenic,* and then has a specific gravity of from 12 to 14, hydrogen being = 1. This is considerably heavier than the usual estimation. If the gas were composed of 1 proportional of arsenic and 2 of hydrogen, without condensation, 100 cubical inches should weigh 51.75 grains, and its specific gravity to hydrogen would be 20.7. But Gay-Lussac and Thenard, (*Recherches Physico-Chimiques,* Tom. i. p. 230.) have shown by decomposing it by tin, that 100 parts expand to 140, which would still increase its specific gravity, it being probable that 3 volumes of hydrogen are condensed into 2. It is probable, therefore, that the gas, hitherto described under the name of arsenuretted hydrogen, is a mixture of the real compound with hydrogen.

1050. The gas obtained by the above-described process is expanded in volume and deposits arsenic at high temperatures: exposure to intense cold is said to occasion its liquefaction. It smells strongly alliaceous; it extinguishes a taper, and burns with a pale blue flame, depositing arsenic and its oxide. If detonated with about 4 volumes of oxygen, arsenious acid and water are formed. According to Stromeyer, (NICHOLSON'S

Journal, Vol. xix.) it requires for its perfect combustion 0.72 parts of its bulk of oxygen; but this is probably not sufficient to burn the arsenic.

1051. If bubbles of chlorine be passed up into a jar of arsenuretted hydrogen, standing over warm water, flame and explosion are often produced, muriatic acid is formed, and a brown hydruret is deposited; but if the gas be passed in the same way by successive bubbles into chlorine, no inflammation results, absorption takes place, and muriatic acid and chloride of arsenic are formed. If the chlorine be not very pure, and when the gases are cold, inflammation seldom follows their mixture.

1052. Chlorine, added to a mixture of sulphuretted with arsenuretted hydrogen, causes a deposit of red sulphuret of arsenic.

1053. Nitric acid suddenly decomposes arsenuretted hydrogen; water, oxide of arsenic, nitrous acid, and nitric oxide are the results.

1054. *Arsenic and Sulphur.*—By slowly fusing a mixture of metallic arsenic and sulphur, or by heating white arsenic with sulphur, a *red sulphuret of arsenic* is obtained. It is crystallizable, and of a vitreous fracture: its specific gravity is 3.4. It is usually known under the name of *realgar*, and occurs *native* in Germany and Switzerland, in veins of primitive rocks and among volcanic matter. Its primitive form is an acute octoëdron.

1055. If white arsenic be dissolved in muriatic acid, and precipitated by hydrosulphuret of ammonia, a fine yellow sulphuret of arsenic falls, which it appears only differs in form from realgar: it is usually called *orpiment.* According to Laugier, (*Annales de Chimie,* lxxxv.) these sulphurets are composed of about 58 arsenic and 42 sulphur, which differs little from 1 proportional and 2, or

44 arsenic + 30 sulphur = 74 sulphuret of arsenic.

1056. *Native Orpiment* is of a bright lemon or golden colour. It is generally massive and lamellar. It occurs both in primitive and secondary rocks in Suabia, Hungary, China, and South America.

1057. M. Braconnot has successfully employed an ammoniacal solution of sulphuret of arsenic as a dye stuff; the process he recommends is as follows: 1 part of sulphur, 2 of white arsenic, and 5 of pearlash, are to be fused in a crucible at a heat a little below redness: a yellow mass results, which is to be dissolved in hot water and filtered; the filtered solution, diluted with water, is to be treated with weak sulphuric acid, and will give a fine yellow precipitate, which easily dissolves in ammonia, forming a solution at first yellow, but becoming colourless on adding more ammonia. The wool, silk, cotton, or linen, is to be dipped into this solution, more or less diluted according to the colour required, care being taken that no metallic vessels are used; on taking them out they are at first colourless, but as the ammonia evaporates become yellow; they are then to be freely exposed to the air, washed and dried. This colour is very permanent, but soap impairs it.

1058. *Sulphuret of Arsenic and Iron* is found native in many parts of Europe. It is of a more silvery colour than iron pyrites, and when heated exhales the odour of arsenic. It is called *arsenical pyrites*, or *mispickel.*

1059. Nothing is known respecting the *Sulphite* or the *Hyposulphite of Arsenic.*

1060. Sulphuric acid is slowly decomposed when boiled upon arsenic. Sulphurous acid is evolved, and difficultly soluble crystalline grains of *sulphate of arsenic* are deposited as the solution cools.

1061. *Phosphuret of Arsenic* is formed by heating the metal, or its oxide, with phosphorus; it is grey and brittle.

1062. Neither the *Hypophosphite* nor *Phosphite of Arsenic* have been examined.

1063. *Phosphate of Arsenic* is formed in difficultly soluble crystalline grains, by boiling white arsenic in phosphoric acid.

1064. There appears to be no *Carbonate of Arsenic.*

1065. Arsenic forms alloys with most of the metals, and they are generally brittle. With potassium it forms a brownish compound, which, when put into water, evolves less hydrogen than pure potassium, in consequence of the formation of hydruret of arsenic With sodium, the alloy is either brown and of an earthy aspect, or grey and metallic, according to the proportions of the metals: water acts upon it as upon the former. (GAY-LUSSAC and THENARD. *Recherches Physico-Chimiques,* Tom. i.) The alloy of arsenic and manganese is not known. With iron, zinc, and tin, it forms white brittle compounds; with copper it forms a white malleable alloy; with lead, a brittle compound of a lamellar texture; with antimony, the alloy is brittle, hard, and very fusible. It combines with bismuth, and probably with cobalt, but these alloys have not been examined.

1066. The separation of arsenic from other metals may generally be accomplished by deflagration with nitre, by which it is acidified, and the arseniate of potassa may afterwards be washed out by hot water.

1067. As arsenic, either accidentally or intentionally taken, is a very frequent cause of death, and often the subject of judicial inquiry, it becomes of importance to point out the most effectual modes of discovering its presence. Where arsenic proves fatal, it is very seldom found in the contents of the stomach after death, but is generally previously voided by vomiting or by stool; and we often can detect it in the matter thrown off the stomach, in the form of a white powder, subsiding in water. The inflammation of stomach which results is generally a secondary effect, and takes place equally, whether the poison be swallowed or applied to a wound.

If minute quantities of white powder be detected, however, in the stomach after death, or in the matter vomited, it is to be carefully collected, and treated as follows:

(*a.*) Mix a small portion of it with about two parts of black flux; introduce the mixture into a glass tube, and gradually heat it red-hot in the flame of a spirit-lamp. If arsenic be present, a *steel-coloured sublimate* will attach itself to the cooler part of the tube, which, heated in contact of air, evaporates in a *white smoke, strongly smelling of garlic.*

(*b.*) Boil the suspected matter in a little distilled water: and when the solution has cooled, add a few drops of solution of sulphuretted hydrogen. If arsenic be present, a *yellow precipitate* will appear.

(*c.*) To the solution *b* add a drop of solution of subcarbonate of potassa, and then a drop or two of solution of sulphate of copper. An *apple-green precipitate* indicates arsenic.

(*d.*) Add to the solution *b* a drop of nitrate of silver, and of solution of ammonia. A *yellow precipitate* indicates arsenic.

It must be observed, in regard to these tests, that the first only is unequivocal, and that the appearances produced by the others may originate from the presence of other substances. When, however, all the above appearances ensue, no doubt of the existence of arsenic can be entertained. The several precipitates should be collected, and will, when placed upon a red-hot iron, exhale the peculiar smell of arsenic. The reader is referred for further particulars on this subject to HENRY'S *Elements of Chemistry*, Vol. ii. p. 480, 8th edit.: to MURRAY'S *System*, Vol. iii. p. 441, 4th edit.: to Dr. BOSTOCK'S *Paper*, in the *Edinb. Med. and Surg. Journal*, Vol. v. p. 166: to Mr. HUME'S *Essay*, in the *Phil. Mag.* Vol. xxxiii.; and *London Med. and Phys: Journal*, Vol. xxiii.: to Dr. MARCET'S *Paper*, in the *Medico-Chirurgical Transactions*, Vol. ii.; and to Mr. SYLVESTER'S *Observations*, in NICHOLSON'S *Journal*, Vol. xxxiii.

SECTION XXIV. *Molybdenum.*

1068. THE sulphuret is the most common natural compound of this metal. To procure the metal, the native sulphuret is powdered and exposed under a red-hot muffle, till converted into a grey powder, which is to be digested in ammonia, and the solution filtered and evaporated to dryness. The residuum is dissolved in nitric acid, re-evaporated to dryness, and violently heated with charcoal. The metal is of a whitish grey colour, and of excessively difficult fusion. According to Hielm, its specific gravity is 7.4; according to Bucholz, it is as high as 8.6.

1069. *Molybdenum and Oxygen.*—When exposed to heat and oxygen, molybdenum is acidified, a white crystalline sublimate of *molybdic acid* being formed.

There are two other compounds of molybdenum with oxygen; the one *brownish black*, obtained by heating molybdic acid with charcoal; the other *blue*, and procured by immersing tin in solution of molybdic acid;

the black oxide consists of 44 M. + 7.5 oxygen
the blue (molybdous acid) 44 M. + 15
the white (molybdic acid) 44 M. + 22.5

Mr. Hatchett, in his *Experiments on the Native Molybdate of Lead*, concludes the metal to be susceptible of four degrees of oxidizement.—*Phil. Trans.*, 1796.

The above numbers are taken from the analyses of

Bucholz, corrected by some experiments of my own, on the molybdic acid; our results are very nearly similar.

1070. To obtain *molybdic acid*, the native sulphuret should be triturated, to reduce it, as far as possible, to powder, and distilled, with three or four parts of nitric acid, to dryness. This operation should be repeated, till the ore is converted into an uniform white mass, which consists of molybdic, nitric, and sulphuric acids; the two latter may be expelled by a red heat, in a platinum crucible, and the remaining molybdic acid repeatedly washed with boiling water, in which it is little soluble, will be nearly pure. It may be rendered perfectly pure by solution in ammonia, precipitation by nitric acid, and exposure to heat.

1071. The molybdic acid, thus procured, is a white powder, of the specific gravity of 3.46, and requiring 960 parts of boiling water for its solution, which is yellow, reddens litmus, but has no sour taste. Heated to redness in an open vessel, it slowly sublimes, and condenses in brilliant yellowish scales. It dissolves in hot sulphuric acid, forming a solution, which is colourless while hot, but on cooling acquires a blue colour, which is heightened by the addition of soda. Its muriatic solution is pale yellowish green, but becomes blue when saturated by potassa.—HATCHETT, *Phil. Trans.* 1796.

1072. *Molybdate of Ammonia* is not crystallizable, and when heated to redness the ammonia is driven off, and the acid converted into oxide of molybdenum.—BUCHOLZ, *Gehlen's Journal*, iv. 616.

1073. *Molybdate of Potassa* is formed by digesting the acid in potassa; or by heating to redness two parts of nitre with one of molybdic acid, and lixiviating the mass. The solution yields small rhomboidal crystals by evaporation, and affords a precipitate of molybdic acid, to muriatic, nitric, and sulphuric acids.

1074. *Molybdate of Soda* is more soluble than molybdate of potassa, and furnishes permanent and transparent crystals. In obtaining both these salts, a deposit of a yellowish powder ensues, which is probably a *bimolybdate* of potassa and of soda.

1075. *Native Molybdate of Lead* occurs principally in crystals of different shades of yellow. It was first discovered in Carinthia, and has since been found in Mexico, Hungary, and Saxony. According to Mr. Hatchett's analysis (*Phil. Trans.* 1796,) it contains 38 molybdic acid + 58.4 oxide of lead; and these numbers closely correspond with its theoretical composition, which should be 1 proportional of molybdic acid = 66.5 + 1 proportional of oxide of lead = 104.5.

1076. *Molybdate of silver, of mercury, of lead,* and *of nickel,* may be procured by adding molybdic acid to the respective nitrates of those metals.

The remaining molybdates have either not been examined, or the accounts of their properties are too much at variance to be depended upon.

1077. *Sulphuret of Molybdenum* is a sectile compound of a metallic lustre, composed of 44 M. + 30 S.

The *native sulphuret* is found in Bohemia, Sweden, and near Mont Blanc, disseminated in a grey granite. It has been found in England, chiefly in Cornwall; and in Scotland, in Inverness-shire. It rarely occurs crystallized; generally massive, and made up of easily separable laminæ. It is soft and unctuous to the touch, and in colour much like lead. It is found exclusively in primitive rocks; generally in granite, and with quartz.

1078. Little is known concerning the salts of molybdenum.

SECTION XXV. *Chromium.*

1079. CHROMIUM was discovered by Vauquelin in 1797. It may be obtained by intensely igniting its oxide with charcoal. Its colour resembles that of iron, and its specific gravity is 5.9. It is brittle, and difficult of fusion.

1080. *Chromium and Oxygen.*—When chromium is exposed to the action of heat and air, it combines with oxygen, and a *green protoxide* is obtained. This oxide easily dissolves in acids.

1081. *Native Protoxide of Chromium* has been found in France, in the department of the Rhone, in the form of a green incrustation. It is the colouring matter of the emerald, and exists in a few other minerals.

1082. When nitrate of chromium is decomposed at a red heat, an insoluble *brown deutoxide* is formed. It does not dissolve in the acids; but when heated with muriatic acid, chlorine is evolved, and a muriate, containing the protoxide, is formed.

1083. *Peroxide of Chromium*, or *chromic acid*, is most easily procured by the decomposition of the native *chromate of lead*, which may be effected by reducing it to a very fine powder, and boiling it in a solution of potassa or soda. An orange-coloured solution of the alcaline chromate is thus formed, to which sulphuric acid is to be added. On evaporation crystals of chromic acid are formed, along with the sulphate of soda or of potassa. Or the acid may be obtained by adding nitrate of baryta to the chromate of potassa, and subsequently decomposing the chromate of baryta which falls, by sulphuric acid.

1084. Chromic acid may also be procured by the following process from native *chromate of iron*, which is a more common mineral than the chromate of lead. Reduce it to a fine powder, and expose it to a red heat for two hours, mixed with half its weight of nitre; wash the contents of the crucible, and add to the lixivium nitric acid sufficient to neutralize the excess of potassa: in this way a solution of nitrate and of chromate of potassa is obtained. Upon adding nitrate of mercury to this solution, *chromate of mercury* is precipitated in the form of a red powder, which, when washed, dried, and heated, is decomposed, and either chromic acid or oxide is obtained.

1085. Chromic acid is of a red colour; its taste is sour and metallic, and it may be obtained from its aqueous solutions in prismatic crystals, of a ruby colour. When heated red hot, it gives out a portion of oxygen, and becomes the green protoxide; it imparts colour to the ruby.

1086. *Native Chromate of Iron* has been found in small crystalline grains, of an octoëdral form. It commonly occurs massive, of a black colour, with a slight metallic lustre, and hard enough to cut glass. It has been found in Siberia, France, and America, and promises to become useful in the arts, as a source of some fine pigments.

1087. *Native Chromate of Lead* is a very rare mineral, hitherto only found in the Uralian mountains in Siberia; it occurs in prismatic crystals, of a fine orange red colour, and is occasionally accompanied by small green crystals, supposed to be *chromite of lead*, or a combination of oxide of chrome and oxide of lead.

1088. Satisfactory experiments on the composition of the oxides of chromium are still wanting. According to Vauquelin, chromate of baryta consists of 62.2 baryta + 37.4 chromic acid, or, speaking in the equivalent numbers adopted in this work, of 1 proportional of baryta = 72.5 + 1 proportional of chromic acid 43.5.

According to Berzelius, the green oxide of chromium contains half the quantity of oxygen existing in the chromic acid. If, therefore, the latter be regarded as a deutoxide, the number 28.5 will represent chromium, and protoxide of chromium would consist of 28.5 chromium + 7.5 oxygen; and chromic acid of 28.5 chromium + 15 oxygen.

1089. The chromates of ammonia, potassa, soda, lime, and magnesia are soluble and crystallizable, and of an orange colour. The chromates of baryta and strontia are difficultly soluble, and may be formed by adding chromate of potassa or soda to their soluble saline compounds. The other insoluble metallic chromates may be formed in the same way, and their colours, which are various and beautiful, often enable us to judge of the nature of the metal present. Thus chromate of soda forms insoluble precipitates in solutions of silver, mercury, lead, copper, iron, and uranium; the colours are crimson, red, orange or yellow, apple-green, brown, and yellow. It forms no precipitate in solutions of nickel, zinc, tin, cobalt, gold, or platinum; whence, perhaps, it may be inferred, that the chromates of the latter metals are soluble.

The chromates are decomposed by muriatic, nitric, and sulphuric acids. Muriatic acid, heated with the chromates, evolves chlorine, the chromic acid being reduced to the state of oxide.

The most correct details respecting the chromates that have been published, are to be found in Vauquelin's *Essay.—Annales de Chimie*, lxx.

1090. The green oxide of chromium is occasionally used in porcelain and enamel painting; and the artificial chromate of lead forms a rich and durable yellow.

The remaining compounds of chromium are as yet unexamined.

SECTION XXVI. *Tungsten.*

1091. THIS metal is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat. It is difficult of fusion, very hard, brittle, and of an iron colour. Its specific gravity 17.5. By the action of heat and air, tungsten is converted into an oxide, which is of a yellow colour. It has been called by some *Scheelium*, by others *wolframium.*

1092. *Peroxide of Tungsten*, or *Tungstic Acid*, may be obtained from two native combinations; the one called *wolfram*, the other *tungstate of lime.*

Wolfram is found in primitive countries generally accompanying tin ores; its colour is brownish black; it occurs massive and crystallized, its primitive form being a rectangular parallelopiped. It abounds in Cornwall. It consists of tungstic acid united with oxides of iron, and manganese. It may be decomposed by ignition with three times its weight of nitre; the fused mass, digested in boiling water and filtered, furnishes a solution, which upon the addition of muriatic acid, gives a precipitate regarded by Scheele as tungstic acid, but which in fact is a compound of muriatic and tungstic acids and potassa. Dissolve this in boiling carbonate of potassa, precipitate by muriatic acid, wash the precipitate, and digest it in nitric acid. Then wash and dry it, and it is pure tungstic acid.—BUCHOLZ, as quoted by THOMSON, *System*, ii. 122.

1093. *Native Tungstate of Lime* is a whitish semi-transparent substance, found in England, Saxony, Bohemia, and Sweden, and occurring crystallized and massive. Its most usual form is the octoëdron. It may be decomposed by fusion with four parts of carbonate of potassa, the fused mass is digested in about twelve parts of boiling water, and filtered. Nitric acid precipitates the peroxide.

1094. *Tungstic Acid,* or *Peroxide of Tungsten,* is tasteless and insoluble in water; its specific gravity is 6. When violently heated it becomes green, grey, and black, probably from the loss of oxygen. It combines with several of the metallic oxides, and was found by Guyton to give considerable permanence to vegetable colours; hence it probably might prove useful in the art of dyeing, were it more abundantly procurable.

According to Dr. Thomson (*System*, Vol. i. p. 553,) tungstic acid is a compound of

Tungsten	100
Oxygen	25

and he regards it as containing one proportional of metal and three of oxygen. Upon these data the number 90 would represent tungsten and the peroxide would contain

90	tungsten
22.5	oxygen
112.5	tungstic acid.

And tungstate of lime would consist of

1 proportional of tungstic acid = 112.5
1 ———————— lime .... = 26.5
139

but this does not agree with Klaproth's experiments, who found tungstate of lime to consist of

77.5 acid
22.5 lime
100

though it is consistent with Berzelius's statement, as reported by Thomson, and which probably is founded on calculation.

Some of the tungstates have been examined by Scheele, and others by Vauquelin and Hecht (*Journal des Mines*, No. 19,) but their history remains very imperfect.

1080. *Tungstate of Ammonia* is procured in crystalline scales, of a metallic taste, by digesting the acid in ammonia or its carbonate. It contains, according to Vauquelin, 78 of acid, and 22 ammonia and water.

1081. *Tungstate of Potassa* is uncrystallizable and deliquescent. The acids occasion precipitates in its solution, which are triple compounds of tungstic acid, potassa, and the acid used as precipitant. The *Nitrotungstate of Potassa* is the salt originally described by Scheele as tungstic acid. It dissolves in 20 parts of water, at 212°, and reddens litmus.

1082. *Tungstate of Soda* crystallizes in hexaëdral tables, soluble in 4 of cold, and 2 parts of boiling water, and of an acrid taste. Sulphuric, nitric, and muriatic acids occasion precipitates, as in the tungstate of potassa.

1083. *Tungstate of Lime*, *of Baryta*, and *of Strontia*, are insoluble white compounds.

1084. *Tungstate of Magnesia* is obtained by boiling the acid with magnesia, filtering, and evaporating; it crystallizes in pearly scales. The acids produce precipitates of triple compounds in its solution.

1085. *Tungstate of Manganese*, formed by adding tungstate of potassa to muriate of manganese, is an insoluble white powder (John, *Gehlen's Journal*, iv.) *Tungstate of Iron* is also insoluble: *Tungstate of Zinc* and *of Tin* have not been examined, nor have any of the remaining tungstates been examined in their pure state.

The remaining compounds of tungsten have scarcely been investigated, and appear of little interest or importance.

SECTION XXVII. *Columbium.*

1086. THIS metal was first discovered by Mr. Hatchett in a mineral from North America. It is found combined with the oxides of iron and manganese, and also with yttria, in the minerals called *tantalite* and *yttro-tantalite*.

1087. Tantalite is chiefly found in octoëdral crystals, and in masses of a black or grey colour, in Finland. Its specific gravity is 7.9, and it contains, according to Ekeberg,

80	oxide of columbium
12	oxide of iron
8	oxide of manganese.

1088. Yttro-tantalite is found in Ytterby, in Sweden. It contains about 45 per cent. of oxide of columbium. Its colour is dark grey, its lustre shining and somewhat metallic.

1089. Columbium was discovered in these minerals by M. Ekeberg, and, considering it as a *new* metal, he called it *tantalum*. In 1809 (*Phil. Trans.*) Dr. Wollaston examined these and the original mineral in the British Museum, and demonstrated the identity of columbium and tantalum. As the former name was given to this body by its original discoverer, it is here retained.

1090. Columbium may be procured from columbite or tantalite, by the following process: Mix 5 parts of the finely-powdered mineral with 25 of carbonate of potassa, and 10 of borax; fuse the mixture, and when cold digest it in muriatic acid; this dissolves every thing except the oxide of columbium, which remains in the form of a white powder (Wollaston, *Phil. Trans.* 1809, p. 248.). From 5 grains of columbite, Dr. Wollaston obtained

Oxide of columbium	4	grains
——— iron	$\frac{3}{4}$	
——— manganese	$\frac{1}{4}$	

From 5 grains of tantalite he procured

Oxide of columbium	$4\frac{1}{4}$	grains
——— iron	$\frac{1}{2}$	
——— manganese	$\frac{2}{10}$	

1091. Berzelius is the only person who has obtained metallic columbium. He describes it as having the colour of iron, very hard and brittle, and burning at a red heat into a whitish oxide.

1092. The characters of white oxide of columbium are very well marked. It is nearly insoluble in muriatic, nitric, and sulphuric acids; it is very soluble in potassa, and carbonate of potassa; 8 grains of the latter, fused with 1 of the oxide, render it soluble in water. It is much less soluble in soda, and only retained while hot. From the readiness with which this oxide combines with potassa, Mr. Hatchett called it *columbic acid.*

1093. *Columbate of Potassa,* as appears from Mr. Hatchett's experiments, forms white glittering scales, like boracic acid. Acids precipitate the columbic acid from this solution.

1094. Infusion of galls, added to the solution of columbate of potassa produces a very characteristic orange-coloured precipitate. Neither ferro-cyanate of potassa, nor hydrosulphurets, occasion any change.

There is a character very peculiar to the oxide of columbium, which is its ready solubility in tartaric, citric, and oxalic acids. In all these cases the newly precipitated oxide must be used, for when dried it becomes very intractable.

1095. According to Berzelius, 100 parts of columbium combine with 5.485 of oxygen; so that the representative of the metal in our numbers will be 139, and of the oxide $139 + 7.5 = 146.5$—THOMSON, Vol. i. p. 558.

The remaining properties of columbium have not been investigated.

SECTION XXVIII. *Nickel.*

1096. NICKEL is found native; combined with arsenic; and with arsenic acid. It is procured pure by the following process: Dissolve the impure metal, sold under the name of *Speiss*, in sulphuric acid, by adding the quantity of nitric acid necessary to produce the solution. Concentrate this solution, and set it aside; fine green crystals of sulphate of nickel make their appearance. Proceed in this manner till you have obtained a sufficient quantity of crystals. Dissolve them in water, and crystallize a second time. If they be now dissolved in water, and decomposed by an alcali, pure oxide of nickel will fall. Mix it with 3 *per cent* of resin, make it into a paste with oil, and expose it to the most violent heat of a forge, in a charcoal crucible. A button of pure nickel will be obtained.—THOMSON'S *System*, i. 391.

1097. Nickel is a white metal, which acts upon the magnetic needle, and is itself capable of becoming a magnet. It is difficultly fusible, but absorbs oxygen readily when heated red-hot. It is malleable, and its specific gravity is about 8.5.

1098. *Oxide of Nickel* is obtained by adding potassa to the solution of the nitrate; a precipitate falls of a pale green colour which is a *hydrate*, or compound of oxide of nickel with water; this, heated to redness, affords a grey oxide, consisting, according to Tuputi

(*Annales de Chimie*, lxxx.) of 100 metal + 27 oxygen; or, in our equivalents, of 28 nickel + 7.5 oxygen = 35.5.

This *protoxide of nickel* easily dissolves in ammonia forming a sapphire blue solution; this property is often made use of to separate oxides of nickel and iron, the latter being insoluble in ammonia.

1099. According to Thenard, if chlorine be passed through a mixture of the hydrate of nickel and water, a black *peroxide* is formed, which, when acted upon by the acids, evolves oxygen, and returns to the state of protoxide.

1100. *Chloride of Nickel.*—When nickel is heated in chlorine a *chloride* results. This compound may also be obtained by heating muriate of nickel to redness in a glass tube; a yellow scaly body is obtained, consisting of 55.5 nickel + 67 chlorine.

1101. *Muriate of Nickel,* formed by dissolving the oxide or carbonate of nickel in muriatic acid, is obtained by evaporation in a confusedly crystalline mass, of an apple-green colour and sweetish taste: it is soluble in about 2 parts of water at 60°.

1102. *Chlorate of Nickel.*—Not examined.

1103. *Iodide of Nickel* may be formed by adding solution of hydriodate of potassa to sulphate or nitrate of nickel; it is of a greenish yellow colour, and insoluble.

1104. *Iodate of Nickel* has not been examined.

1105. *Nitrate of Nickel* is a green deliquescent salt, difficultly crystallizable in rhomboids. The analyses of this salt are much at variance, but it probably consists of 1 proportional of each of its components, or

35.5 oxide of nickel
50.5 nitric acid
86

The crystals contain 3 proportionals of water.

1106. By adding excess of ammonia to nitrate of nickel, and evaporating, green crystals of *ammonio-nitrate of nickel* are obtained, the solution of which affords no precipitate with potassa or soda.

1107. *Sulphuret of Nickel* may be formed by fusion. It is a brittle yellow compound.

1108. Neither the *Hyposulpite* nor the *Sulphite of Nickel* have been examined.

1109. *Sulphate of Nickel* is formed by digesting the oxide in dilute sulphuric acid. A bright green solution is formed, which affords quadrangular prismatic crystals, soluble in about 3 parts of water at 60°, and which effloresce by exposure. Their taste is sweet and astringent. This salt is also obtained by heating common nickel in sulphuric acid, with the occasional addition of nitric acid. (1096.)

The crystallized sulphate of nickel contains 7 proportionals of water, and is composed as follows:

1 proportional of oxide = 35.5
1 ——————— acid = 37.5
7 ——————— water = 59.5
132.5

1110. *Sulphate of Ammonia and Nickel* is formed by evaporating a mixed solution of ammonia, and sulphate of nickel; it forms four-sided prismatic crystals.

1111. *Sulphate of Potassa and Nickel* is obtained by adding potassa to sulphate of nickel (not in excess,) filtering and evaporating. It forms green rhomboidal crystals.

1112. *Sulphate of Nickel and Iron* is formed by dissolving the mixed protoxides in sulphuric acid. It is a green efflorescent salt, in tabular crystals.

1113. Sulphuretted hydrogen and hydrosulphuret of ammonia produce a black precipitate of *hydrosulphuretted oxide of nickel,* when added to the solution of the metal.

1114. *Phosphuret of Nickel* is a brittle whitish compound.

1115. *Hypophosphite* and *Phosphite of Nickel* remain unexamined.

1116. *Phosphate of Nickel* being nearly insoluble, is precipitated, upon adding phosphate of soda to a solution of nickel. It is of a pale green colour.

1117. *Carbonate of Nickel* is precipitated in the form of a green powder, when carbonate of potassa is added to sulphate of nickel. It is probably a compound of 1 proportional of each of its components.

35.5	oxide of nickel
20.7	carbonic acid
56.2	

1118. *Borate of Nickel* is a pale green insoluble compound.

1119. Ferrocyanate of potassa occasions a very characteristic pale grey precipitate in dilute solutions of nickel: in concentrated solutions the precipitate is pale green.

1120. Arseniate of potassa, dropped into nitrate of nickel, occasions the precipitation of a pale green *arseniate of nickel.*

1121. The salts of nickel are distinguished by the fine green colour of their solutions, and by affording a green precipitate with ammonia, soluble in excess of that alcali, when it assumes a blue colour. The yellow green precipitate afforded by hydriodate of potassa is very characteristic of nickel; but the nicest test of its presence is the ferrocyanate of potassa, which produces a pale grey or greenish white precipitate in all the solutions of the metal.

1122. Of the *Alloys of Nickel* there is one which requires particular notice, namely, that with iron, which forms the principal metallic ingredient in those lapideous masses, which, in different countries, have fallen upon our globe, and which have been termed *aërolites*, or *meteoric stones.* Though we really know nothing of the source or origin of these bodies, it has been ascertained upon the most satisfactory and indisputable evidence, that they are not of terrestrial formation; and, consequently, since men began to think and reason correctly, their visits to our planet have awakened much speculation, and some experimental research.

In the first place, it deserves to be remarked, that we have very distinct evidence of the falling of stony bodies from the atmosphere in various countries, and at very remote periods. For, to say nothing of the fabulous narrations which encumber the annals of ancient Rome, or the extended catalogue of wonders flowing from the lively imagination of oriental writers, such events are recorded in holy writ, and have been set down by the most accredited of the early historians; and although philosophic scepticism long contended against the admission of the fact, it has in modern times received such unanswerable proofs, as to be allowed by all who have candidly considered the evidence, and is only rejected by the really ignorant, or by those who, for the sake of singularity, affect disbelief.

The first tolerably accurate narration of the fall of a meteoric stone relates to that of Ensisheim, near Basle, upon the Rhine. The account which is deposited in the church runs thus: A.D. 1492, Wednesday, 7 November, there was a loud clap of thunder, and a child saw a stone fall from heaven: it struck into a field of wheat, and did no harm, but made a hole there. The noise it made was heard at Lucerne, Tilling, and other places; on the Monday, King Maximilian ordered the stone to be brought to the castle, and after having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Royal Excellency strictly forbade any body to take any thing from it. His Excellency, however, took two pieces himself, and sent another to Duke Sigismund of Austria. This stone weighed 255 lbs.

In 1627, 27th November, the celebrated Gassendi saw a burning stone fall on Mount Vaisir, in Provence: he found it to weigh 59 lbs.

In 1672, a stone fell near Verona, weighing 300 lbs. And Lucas, when at Larissa, in 1706, describes the falling of a stone, with a loud hissing noise, and smelling of sulphur.

In September, 1753, de Lelande witnessed this extraordinary phænomenon, near Pont de Vesle. In 1768, no less than three stones fell in different parts of

France. In 1790, there was a shower of stones near Agen, witnessed by M. Darcet, and several other respectable persons. And on the 18th of December, 1795, a stone fell near Major Topham's house, in Yorkshire; it was seen by a ploughman and two other persons, who immediately dug it out of the hole it had buried itself in; it weighed 56 lbs.

We have various other, and equally satisfactory, accounts of the same kind. All concur in describing a luminous meteor, moving through the air in a more or less oblique direction, attended by a hissing noise, and the fall of stony or semi-metallic masses, in a state of ignition. We have, however, evidence of another kind, amply proving the peculiarities of these bodies. It is, that although they have fallen in very different countries, and at distant periods, when submitted to chemical analysis they all agree in component parts; the metallic particles being composed chiefly of nickel and iron; the earthy, of silica and magnesia.

1123. Large masses of *native iron* (721) have been found in different parts of the world, of the history and origin of which nothing very accurate is known. Such are the great block of iron at Elbogen, in Bohemia; the large mass discovered by Pallas, weighing 1600 lbs., near Krasnorjark, in Siberia; that found by Goldberry, in the great desert of Zahra, in Africa; probably, also, that mentioned by Mr. Barrow, on the banks of the great fish river in Southern Africa; and those noticed by Celis, Bruce, Bougainville, Humboldt, and others in America, of enormous magnitude, exceeding 30 tons in weight. That these should be of the same source as the other meteoric stones, seems at first to startle belief; but when they are submitted to analysis, and the iron they contain found alloyed with nickel, it no longer seems credulous to regard them as of meteoric origin. We find nothing of the kind in the earth.

1124. To account for these uncommon visitations of metallic and lapideous bodies, a variety of hypotheses have been suggested.

Are they merely earthly matter, fused by lightning? Are they the offspring of any terrestial volcano? These were once favourite notions; but we know of no instance in which similar bodies have in that way been produced, nor do the lavas of known volcanos in the least resemble these bodies; to say nothing of the inexplicable projectile force that would here be wanted. This is merely explaining what is puzzling, by assuming what is impossible; and the persons who have taken up this conjecture, have assumed one impossibility to account for what they conceive to be another, namely, that the stony bodies should come from any other source than our own globe.

The notion that these bodies come from the moon, is, when impartially considered, neither absurd nor impossible. It is quite true, that the quiet way in which they visit us is against such an origin; it seems, however, that any power which would move a body 6000 feet in a second, that is, about three times the velocity of a cannon-ball, would throw it from the sphere of the moon's attraction into that of our earth. The cause of this projective force may be a volcano, and if thus impelled, the body would reach us in about two days, and enter our atmosphere with a velocity of about 25000 feet in a second. Their ignition may be accounted for, either by supposing the heat generated by their motion in our atmosphere sufficient to ignite them, or by considering them as combustibles, ignited by the mere contact of air.

While we are considering the *possibility* of these opinions, it may be remembered, that in the great laboratory of the atmosphere, chemical changes *may* happen, attended by the *production* of iron and other metals; that, at all events, such a circumstance is within the range of possible occurrences; and that the meteoric bodies which thus salute the earth with stony showers, may be children of the air, created by the union of simpler forms of matter. The singular relationship between iron and nickel, and magnetism, and the uniform influence of meteoric phænomena on the magnetic needle, should be taken into account in these hypotheses.

1125. Meteoric stones have generally an uneven black surface, and are internally of a grey colour and coarse texture. When carefully examined, they appear made up of a number of small spherical bodies and metallic grains imbedded in a softer matter, composed, according to Mr. Howard, (*Phil. Trans.*, 1802.) of silica, magnesia, and iron with a little nickel: the spherical bodies are nearly of similar composition; and the metallic grains are partly *meteoric iron*, and partly the same with a little sulphur. In addition to these substances, Vauquelin found 2 *per cent.* of chrome in a stone which fell at Langres, in 1815. (*Ann. de Chim. et Phys.*, i. 53.) And Stromeyer detected cobalt in the meteoric iron from the Cape of Good Hope. (THOMSON'S *Annals*, ix.) Lime and alumine have also been found in them, and a small proportion of manganese. M. Laugier has lately announced the existence of a meteoric stone without nickel, but containing chrome; and as he has detected the latter metal in all the aërolites which he has examined, he considers it as their most characteristic ingredient.—*Mem. du Museum*, vi.

1126. In meteoric iron the proportion of nickel varies considerably. In a specimen from the Arctic region I found 3.2 *per cent.* (*Quarterly Journal*, vi. 369.) In that from Siberia, Mr. Children found nearly 10 *per cent.* The analysis may be performed by solution in nitro-muriatic acid; the iron is thrown down by excess of ammonia in the state of peroxide, of which 100 grains indicate 70 of metallic iron; it is separated by filtration, washed and dried, and on evaporating the filtrated liquor and heating its dry residue red-hot, the oxide of nickel is obtained, which should be re-dissolved in nitric acid and precipitated by pure potassa, the mixture being boiled for a few seconds. 100 grains of this oxide of nickel are equal to 79 of metallic nickel.—CHILDREN, *Quarterly Journal*, ix. 324.

1127. Meteoric iron has been imitated by fusing iron with nickel. The alloy of 90 iron with 10 nickel is of a whitish yellow cast, and not so malleable as pure iron. The alloy with 3 *per cent.* of nickel is perfectly malleable and whiter than iron. These alloys are less disposed to rust than pure iron, but nickel alloyed with steel increases the tendency to rust.—STODART and FARADAY, *Quarterly Journal of Science and Arts*, ix.

1128. The remaining alloys of nickel have been little examined. Nothing is known of its compounds with potassium, sodium, manganese, zinc, or tin. With copper it forms a hard white alloy, which appears to be the *white copper* of the Chinese. Its other alloys have not been examined.

SECTION XXIX. *Mercury.*

1129. THE principal ore of this metal is the sulphuret, or *native cinnabar*, from which the mercury is separated by distillation with quicklime or iron filings.

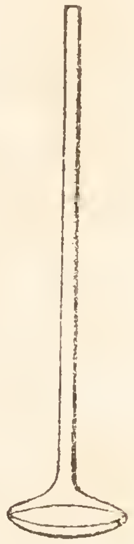
Mercury is a brilliant white metal, having much of the colour of silver, whence the terms *hydrargyrum*, *argentum vivum*, and *quicksilver*. It has been known from very remote ages. It is liquid at all common temperatures, solid and malleable at —40°, and it boils and becomes vapour at about 670°. Its specific gravity is 13.5.

1130. Mercury is sometimes adulterated with the alloy of lead and bismuth, a fraud easily detected by the want of its due fluidity, and by its not being perfectly volatile, but leaving a residuum when boiled in a platinum or iron spoon. The best method of purifying mercury is to re-distil it in an iron retort.

1131. *Native Mercury* occurs in small fluid globules, in most of the mines producing the ores of this metal.

1132. *Mercury and Oxygen.*—There are two oxides of mercury. The *black*, or *protoxide*, may be obtained by long agitation of the metal in contact with oxygen, or by washing the *chloride of mercury* (calomel) with hot lime-water. It is insipid, and insoluble in water, and was called in old pharmacy, *Ethiops per se.*

1133. The *red* or *peroxide* of mercury is produced by exposing the metal, heated nearly to its boiling point, to the action of air. It becomes coated with reddish brown scales, spangles, and crystals, and is ultimately entirely converted into a red shining mass, called in old pharmaceutical works, *precipitate per se*, or *calcined mercury.* It is the *hydrargyri oxydum rubrum* of the present *London Pharmacopœia.* It is most easily obtained by introducing into a flat-bottomed matrass, of the annexed shape, about 4 ounces of mercury, and placing it in a sand bath, heated to the boiling point of the metal. In about a month's time nearly the whole is converted into oxide. Air is freely admitted by the tube, while its length prevents the escape of mercurial vapour, which condenses and falls back into the body of the vessel; the remaining portion of running mercury may be driven off by exposing it in a basin to a heat just below redness.



1134. Peroxide of mercury has an acrid metallic taste, and is poisonous; it dissolves very sparingly in water. When heated, it acquires a black colour, but becomes again red on cooling; at a red heat it evolves oxygen, and is reduced to the metallic state. It should be entirely volatilized when placed upon a red-hot iron, for it is sometimes adulterated with red lead.

1135. Though it is difficult to obtain a perfectly pure black oxide of mercury, it appears to have been demonstrated that it contains just half the quantity of oxygen contained in the red oxide.

The best analyses of the red oxide give as its component parts,

Mercury......	92.7
Oxygen	7.3
	100.0

If we consider this as a compound of 1 proportional of mercury and 2 of oxygen, we obtain the number 190 as the representative of mercury; for

$$7.3 : 92.7 :: 15 : 190.$$

The protoxide, therefore, will consist of

190 Mercury + 7.5 Oxygen = 197.5 Protoxide.

And the peroxide of

190 Mercury + 15 Oxygen = 205 Peroxide.

The black oxide exists in the *pilula hydrargyri,* and in the mercurial ointment of the *Pharmacopæia.*

1136. *Mercury and Chlorine* combine in 2 proportions, and a protochloride and perchloride of mercury are the results. These compounds are usually called *calomel* and *corrosive sublimate.* In the *London Pharmacopæia* they have received the improper names of *submuriate of mercury* and *oxymuriate of mercury.*

1137. *Protochloride of Mercury.*—This compound, commonly termed *calomel*, is first mentioned by Crollius, early in the seventeenth century. The first directions for its preparation are given by Beguin, in the *Tyrocinium Chemicum*, published in 1608. He calls it *draco mitigatus*. Several other fanciful names have been applied to it, such as *aquila mitigata, manna metallorum, panchymagogum minerale, sublimatum dulce, mercurius dulcis*, &c.

The most usual mode of preparing calomel consists in triturating two parts of corrosive sublimate with one of mercury, until the globules disappear, and the whole assumes the appearance of an homogeneous grey powder, which is introduced into a matrass, placed in a sand heat, and gradually raised to redness. The calomel sublimes, mixed with a little corrosive sublimate, the greater part of which, however, being more volatile than the calomel, rises higher in the matrass; that which adheres to the calomel may be separated, by reducing the whole to a fine powder, and washing in large quantities of hot distilled water. Pure calomel, in the form of a yellowish white insipid powder, remains.

It was formerly the custom to submit calomel to very numerous sublimations, under the idea of rendering it *mild;* but these often tended to the production of corrosive sublimate; and the calomel of the first sublimation, especially if a little excess of mercury be found in it, is often more pure than that afforded by subsequent operations.

1138. The following are the directions given in the last *London Pharmacopœia:*

" Take of oxymuriate of mercury, 1 lb.
——— purified mercury, *by weight*, 9 oz.

Rub them together, until the metallic globules disappear; then sublime: take out the sublimed mass, reduce it to powder, and sublime it in the same manner twice more successively. Lastly, bring it to the state of a very fine powder; throw this into a large vessel, full of water; then stir it, and, after a short interval, pour the supernatant turbid solution into another vessel, and set it by, that the powder may subside. Lastly, having poured away the water, dry the powder."—Powell's *Translation of the London Pharmacopœia*, Lond. 1815. p. 144 and 99.

1139. It will be observed, that in these processes the operation consists in reducing the perchloride to the state of protochloride by the addition of mercury. Various modes have, however, been adopted for the direct formation of calomel: two of these may here be noticed, of which the first is in the humid way, as devised by Scheele and Chenevix. It is as follows:

Form a nitrate of mercury, by dissolving as much mercury as possible in hot nitric acid; then dissolve in boiling water a quantity of common salt, equal to half the weight of the mercury used, and render the solution sensibly sour by muriatic acid, and pour the hot nitrate of mercury into it. Wash and dry the precipitate.

If this process be carefully performed, and the precipitate thoroughly edulcorated, the calomel is sufficiently pure.

1140. The second process, however, or that by which calomel is directly formed in the dry way, appears, on the whole, the least exceptionable for the production of this very important article of pharmacy; it is the method followed at Apothecaries' Hall, sanction having been obtained for its adoption from the College of Physicians.

50 lbs. of mercury are boiled with 70 lbs. of sulphuric acid, to dryness, in a cast-iron vessel: 62 lbs. of the dry salt are triturated with 40½ lbs. of mercury, until the globules disappear, and 34 lbs. of common salt are then added. This mixture is submitted to heat in earthen vessels, and from 95 to 100 lbs. of calomel are the result. It is to be washed in large quantities of distilled water, after having been ground to a fine and impalpable powder.

1141. Protochloride of mercury is usually seen in the form of a white mass, of a crystalline texture; and when very slowly sublimed, it often presents regular four-sided prisms, perfectly transparent and colourless. Its specific gravity is 7.2. It is tasteless, and very nearly insoluble in water. It can scarcely be called poisonous, since in considerable doses it only proves purgative. By exposure to light it becomes brown upon its surface. If scratched, it gives a yellow streak, which is very characteristic, and does not belong to the perchloride. When very finely levigated it becomes of a buff colour.

It consists of 1 proportional of mercury 190 + 1 proportional of chlorine 33.5, and its representative number is 223.5.

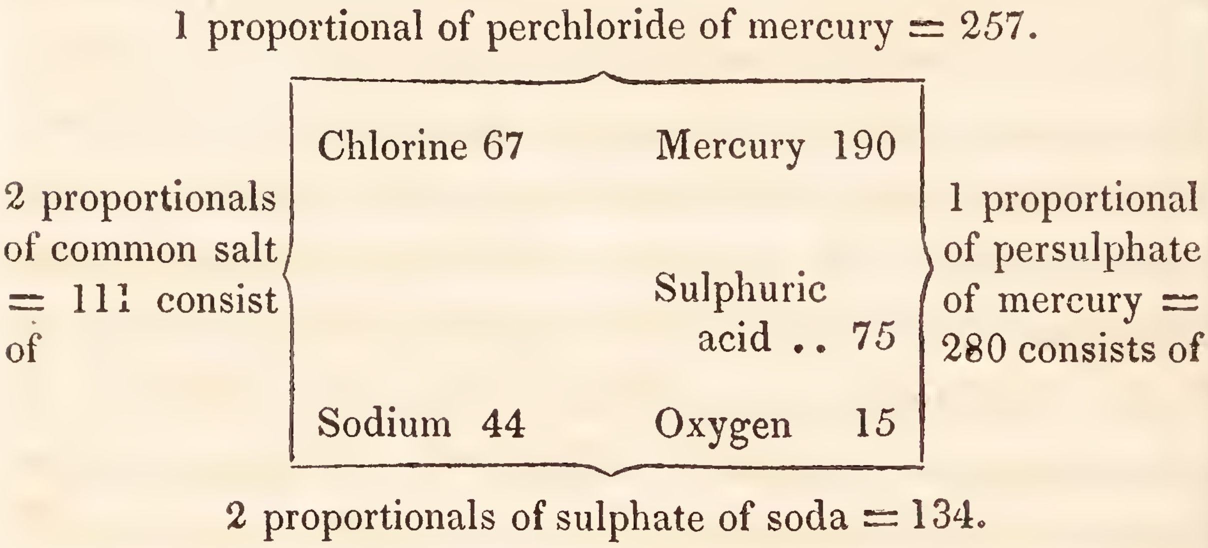
1142. *Native Chloride of Mercury*, or *mercurial horn ore*, has been found in Germany, France, and Spain, usually crystallized, and sometimes incrusting and massive.

1143. *Perchloride of Mercury*, or *corrosive sublimate*, may be obtained by a variety of processes.

When mercury is heated in chlorine, it burns with a pale flame; the gas is absorbed, and a white volatile substance rises, which is the perchloride.

It may also be obtained by dissolving peroxide of mercury in muriatic acid, evaporating to dryness, redissolving in water, and crystallizing.

1144. The ordinary process for making corrosive sublimate consists in exposing a mixture of chloride of sodium (common salt) and persulphate of mercury, to heat in a flask, or other proper subliming vessel; a mutual decomposition ensues. The chlorine of the common salt unites to the mercury of the sulphate, and forms bi-chloride of mercury. The oxygen of the oxide of mercury converts the sodium of the salt into soda, which, with the sulphuric acid, produces sulphate of soda. This decomposition is exhibited by the following diagram:



1145. The following are the official directions of the *London Pharmacopœia*, for the preparation of corrosive sublimate, there termed *oxymuriate of mercury*.

"Take of purified mercury, *by weight*, 2 lbs.
—— sulphuric acid, *by weight*, 30 oz.
—— dried muriate of soda, 4 lbs.

Boil the mercury with the sulphuric acid in a glass vessel, until the sulphate of mercury is left dry. Rub-this when it is cold with the muriate of soda in an earthen-ware mortar; then sublime it in a glass cucurbit, increasing the heat gradually."—POWELL's *Translation.*

The quantity of common salt employed in this process is obviously too large; in practice, however, we find that more than the real quantity decomposed, and shown in the above table, is required.

1146. The following is the process employed at Apothecaries' Hall for the formation of corrosive sublimate: 50 lbs. of mercury are boiled to dryness with 70 lbs. of sulphuric acid. 73 lbs. of persulphate of mercury are thus formed, which being perfectly mixed with 120 lbs. of common salt and sublimed, yield from 63 to 65 lbs. of corrosive sublimate.

1147. By the quantity of chlorine absorbed by a given weight of mercury, we learn that the perchloride of mercury consists of 1 proportional of mercury $= 190 + 2$ proportionals of chlorine $= 67$, consequently, its representative number is 257.

1148. Perchloride of mercury is usually seen in the form of a perfectly white semi-transparent mass, exhibiting the appearance of imperfect crystallization. It is sometimes procured in quadrangular prisms. Its specific gravity is 5.2. Its taste acrid and nauseous, and leaving a peculiar metallic and astringent flavour upon the tongue. It dissolves in 20 parts of water at 60°, and in about half its weight at 212°. It is more soluble in alcohol than in water. When heated, it readily sublimes in the form of a dense white vapour, strongly affecting the nose and mouth. It dissolves without decomposition in muriatic, nitric, and sulphuric acids:

the alcalis and several of the metals decompose it. It produces, with muriate of ammonia, a very soluble compound; hence a solution of sal-ammoniac is used with advantage in washing calomel to free it from corrosive sublimate.

1149. Protochloride and perchloride of mercury are decomposed by potassa, soda, and lime; the former affords *black*, (*hydrargyri oxidum cinereum* of the *London Pharmacopæia*,) the latter *red*, oxide of mercury; and the chlorides of potassium, sodium, and calcium, are produced. The following diagrams shew the interchange of elements that takes place in the case of adding a solution of potassa to protochloride and perchloride of mercury.

1 proportional of chloride of potassium = 71.

1 proportional of protochloride of mercury 223.5.	Chlorine 33.5	+	Potassium 37.5	1 proportional of potassa = 45.
	Mercury 190	+	Oxygen 7.5	

1 proportional of protoxide of mercury = 197.5.

2 proportionals of chloride of potassium = 142.

1 proportional of perchloride of mercury = 257.	Chlorine 67	+	Potassium 75	2 proportionals of potassa = 90.
	Mercury 190	+	Oxygen 15	

1 proportional of peroxide of mercury = 205.

1150. When solution of ammonia is poured upon calomel, protoxide of mercury, and muriate of ammonia, are the results; but ammonia, added to a solution of corrosive sublimate, occasions a white precipitate of a *triple muriate of ammonia and mercury.*

A compound of this kind has long been used in pharmacy, under the name of *calx hydrargyri alba,* or *white precipitate.* The *London Pharmacopœia* directs the following process for its formation.

> " Take of oxymuriate mercury ½ lb.
> —— muriate of ammonia 4 oz.
> —— solution of subcarbonate of potassa ½ pint.
> —— distilled water 4 pints.

First dissolve the muriate of ammonia, then the oxymuriate of mercury, in the distilled water, and add thereto the solution of subcarbonate of potassa. Wash the precipitated powder until it becomes tasteless: then dry it."

1151. Muriate of ammonia renders corrosive sublimate more soluble in water, one part rendering five parts soluble in rather less than five of water. By evaporation a triple salt is obtained, formerly called *sal alembroth.* The addition of potassa or soda throws down the above-mentioned white precipitate. Hence its use in washing calomel.

1152. *Chlorate of Mercury.*—Chloric acid dissolves both the oxides of mercury; the *protochlorate* has the appearance of a yellowish granular powder, sparingly soluble in hot water, and of a mercurial taste. The *perchlorate* forms white acicular crystals, having the acrid flavour of the perchloride.—VAUQUELIN, *Annales de Chimie,* xcv.

1153. *Mercury and Iodine* unite in two proportions. These compounds may be procured either by gently heating mercury with iodine, or by adding hydriodic acid to solutions of mercury. The *protiodide* is yellow, and the *periodide* red. They respectively consist of 1 proportional of mercury + 1 of iodine and 1 + 2. They are both insoluble in water.

1154. *Iodate of Mercury.*—Iodate of potassa occasions a precipitate in protonitrate of mercury, but not in the pernitrate.

1155. *Mercury and Nitric Acid.*—Nitric acid is rapidly decomposed by mercury; nitrous acid, and nitric oxide gases are evolved, and either a protonitrate or a pernitrate of mercury are obtained, according to the mode in which the solution is performed.

1156. *Protonitrate of Mercury* is best obtained by dissolving the metal in a cold and dilute acid, consisting of one part of acid and three of water; the metal should be added in small successive portions until the acid ceases to act upon it, and care should be taken to keep the whole cold. This solution deposits transparent crystals which appear to be modified octoëdra, and which consist of the protoxide of mercury combined with nitric acid. They are soluble without decomposition in cold water, and the solution affords black precipitates of protoxide, upon the addition of the alcalis.

1157. *Pernitrate of Mercury.*—When mercury is dissolved in hot and concentrated nitric acid, it becomes peroxidized, and furnishes prismatic crystals of the pernitrate. Their solution furnishes yellow or red precipitates of peroxide of mercury, upon the addition of potassa or soda, and ammonia forms a white precipitate which is a *triple nitrate of mercury and ammonia.*

When the precautions in forming the nitrates above described are not attended to, the solution usually contains a mixture of the two nitrates, and furnishes a precipitate with the alcalis, composed of both oxides. The pernitrate is most certainly formed by dissolving the red oxide in nitric acid.

1158. When hot water is poured upon pernitrate of mercury, a yellow insoluble powder separates from it, which is a *subpernitrate*, the *nitrous turpeth* of old writers; and a *super-pernitrate* remains in solution. It seems probable that the protonitrate is also capable of affording a sub and a super nitrate; but all these compounds have hitherto been but imperfectly investigated, and new researches are wanting to establish their nature and composition.

If the protonitrate and pernitrate be composed of one proportional of each of the oxides with one of acid and with two of acid, the following will be their component parts.

197.5	protoxide	205	peroxide
50.5	nitric acid	101	nitric acid
248.	protonitrate of M.	306	pernitrate of M.

The subpernitrate has been analyzed by M. M. Braamcamp and Oliva, (*Thomson*, Vol. ii. p. 635), and they report its composition at

12	acid
88	peroxide
100	

If its composition in theory be admitted as 2 proportionals of peroxide = 410 + 1 proportional of nitric acid = 50.5, these numbers are not much at variance with the above experimental result.

1159. When these nitrates of mercury are exposed to heat gradually raised to dull redness, nitric acid is given off; and a brilliant red substance remains, consisting of peroxide of mercury with a small portion of adhering nitrate. This is used in pharmacy as an escharotic, and is called in the *London Pharmacopœia*, *hydrargyri nitrico-oxidum.*

In the manufacture of this compound at Apothecaries' Hall, 100 lbs. of mercury are boiled with 48 lbs. of nitric acid (sp. gr. 1.48), and by proper evaporation and application of a dull red heat, 112 lbs. of the *hydrargyri nitrico-oxidum* are obtained.

1160. *Mercury and Sulphur.*—When one part of mercury is triturated for some time with three of sulphur, a black tasteless compound is obtained, which was called in old pharmacy *Ethiops Mineral;* it is, however, no longer retained in the *London Pharmacopœia.*

The same substance is more readily formed by pouring mercury into melted sulphur, the substances quickly combine, with such a rise of temperature as often produces inflammation.

1161. There is some difficulty in ascertaining how far these are definite compounds; when, however, sulphuretted hydrogen is passed through a dilute solution of nitrate of mercury, a black powder is thrown down, which appears to be a true sulphuret, and which, according to Guibourt, (*Annales de Chimie et*

Phys., Tom. i.) consists of 100 mercury + 8.2 sulphur, numbers which correspond to

1	proportional mercury	= 190
1	———— sulphur	= 15
	Sulphuret of mercury	= 205

1162. When the black sulphuret is heated red hot in a flask, a portion of mercury evaporates, and a sublimate of a steel grey colour is obtained, which, when reduced to a fine powder, assumes a brilliant red colour, and is called *vermilion,* or *cinnabar.* It is, in fact, a *bisulphuret of mercury,* and consists of

1	proportional of mercury	= 190
2	———— sulphur	= 30
	Bisulphuret of mercury	= 220

1163. In the manufacture of cinnabar 8 parts of mercury are mixed in an iron pot with 1 of sulphur, and made to combine by a moderate heat, and constant stirring: this compound is then transferred to a glass subliming vessel, (on a small scale, a Florence flask answers perfectly), and heated to redness in a sand bath; a quantity of mercury and of sulphur evaporate, and a sublimate forms which is removed, and rubbed or levigated into a very fine powder.

1164. Cinnabar is not altered by exposure to air or moisture: when heated to dull redness in an open vessel, the sulphur forms sulphurous acid, and the mercury escapes in vapour. It is decomposed by distillation with fixed alcalis, lime, and baryta, and by several of the metals. When adulterated with red lead it is not entirely volatile.

1165. Cinnabar may be made in the humid way by long trituration of mercury and sulphur in solution of potassa.—NICHOLSON'S *Journal*, iv. to ii.

1166. *Native Cinnabar* is the principal ore of mercury: it occurs massive and crystallized in six-sided prisms, rhombs, and octoëdra. It is of various colours, sometimes appearing steel grey, at others bright red. It occurs in Hungary, France, and Spain, in Europe: in Siberia, and Japan, in Asia; and in considerable quantities in South America. The mines of Almaden, and of New Spain, are the most productive, and furnish fine cabinet specimens. Native mercury, and native amalgam of silver sometimes accompany it.

1167. *Hyposulphite of Mercury* appears not to exist: when a solution of a hyposulphite is poured into a very dilute solution of protonitrate of mercury it occasions a black precipitate.

1168. *Sulphite of Mercury* has not been examined.

1169. *Mercury and Sulphuric Acid.*—When mercury is boiled in its weight of sulphuric acid, sulphurous acid gas is evolved, a part of the metal is oxydized and dissolved, and a white deliquescent mass is obtained, which, washed with cold water, affords a very difficultly soluble white salt, which is a *protosulphate of mercury.* It requires 500 parts of water for its solution and crystallizes in prisms. According to Fourcroy (*Annales de Chimie,* x.) it consists of

12	sulphuric acid
83	protoxide of mercury
5	water.

According to theory, it should consist of one proportional of sulphuric acid + 1 of protoxide, or

37.5	sulphuric acid
197.5	protoxide of mercury
235	sulphate of mercury.

The alcalis precipitate black oxide of mercury from this salt.

1170. If three parts of sulphuric acid be boiled to dryness with one of mercury, a white mass of *persulphate of mercury* is obtained; it is more soluble than the sulphate, and crystallizes in prisms. According to Braamcamp and Oliva, it is composed of

31.8	acid
63.8	peroxide
4.4	water
100.0	

It should consist, according to theory, of 1 proportional of peroxide + 2 proportionals of acid.

1171. When hot water is poured upon persulphate of mercury, a yellow insoluble *subpersulphate* is formed, formerly called *Turpeth mineral.* It appears to consist of 1 proportional of peroxide + 1 of acid, or

205.	peroxide of mercury
37.5	sulphuric acid
242.5	subpersulphate of mercury.

A *bipersulphate* remains in solution.

1172. The solutions of persulphate of mercury furnish red precipitates with the fixed alcalis, and white with ammonia, the latter being a triple *sulphate of ammonia and mercury*.

1173. Sulphuretted hydrogen produces a black precipitate in solutions of mercury when added in excess, and which appears to be a sulphuret of mercury.

1174. *Phosphuret of Mercury* may be formed by heating phosphorus with oxide of mercury. It is a sectile solid of a bluish black colour.

1175. Neither the *Hypophosphite* nor *Phosphite of Mercury* have been examined.

1176. *Mercury and Phosphoric Acid.*—When phosphate of soda is added either to nitrate or pernitrate of mercury, a white precipitate is formed. There is probably a *protophosphate* and a *perphosphate*. The latter is soluble in excess of acid.

1177. *Mercury and Carbonic Acid.*—Alcaline carbonates produce buff-coloured precipitates in solutions of both oxides of mercury. These are probably the *protocarbonate* and the *percarbonate*.

1178. *Mercury and Cyanogen.*—By boiling one part of finely powdered red oxide of mercury with two of Prussian blue, in eight parts of water, a solution is obtained, which, if filtered while hot, deposits, on cooling, yellowish white crystals in the form of quadrangular prisms, of a metallic taste and very poisonous, consisting, according to Gay-Lussac, of 80 mercury + 20 cyanogen. They are, therefore, a *cyanuret of mercury*, and probably contain 1 proportional of mercury = 190 + 2 of cyanogen = 48.8.

1179. Cyanuret of mercury is decomposed by heat, as in the process for obtaining cyanogen; and if distilled with muriatic acid, hydrocyanic acid and chloride of mercury are formed. It also is decomposed by hydriodic acid and by sulphuretted hydrogen, an iodide and a sulphuret of mercury, and hydrocyanic acid, being formed. The alcalis do not act upon this cyanuret.

1180. Cyanuret of mercury is also formed by boiling peroxide of mercury in solution of ferrocyanate of potassa; a portion of mercury and of peroxide of iron are at the same time deposited, whence it appears that the oxygen of the mercurial oxide is partly transferred to the iron, and partly to the hydrogen of the ferrocyanic acid.

1181. Cyanuret of mercury boiled in water with peroxide of mercury produces a compound which forms small granular crystals consisting of cyanuret and oxide of mercury; hence in making the cyanuret by the above process (1178) excess of mercurial oxide should be avoided.

1182. *Borate of Mercury*, obtained by adding borate of soda to nitrate of mercury, is a yellow insoluble powder.

1183. *Arseniates of Mercury.*—Arsenic acid occasions a pale yellow precipitate in solution of protonitrate of mercury, and a yellowish white precipitate in solution of the pernitrate. Arsenious acid produces white precipitates in both solutions.

1184. Molybdic acid occasions a white precipitate in solution of nitrate of mercury.

1185. *Chromate of Mercury.*—Chromate of potassa throws down an orange-coloured precipitate from the solutions of nitrate and pernitrate of mercury.

1186. *Tungstate of Mercury.*—Not examined.

1187. The soluble salts of mercury furnish whitish precipitates with ferrocyanate of potassa, and black with sulphuretted hydrogen. A plate of copper, immersed into their solutions, occasions the separation of metallic mercury.

The insoluble mercurial salts are mostly entirely volatilized at a red heat; if distilled with charcoal, they afford metallic mercury.

1188. Mercury combines with most of the other metals, and forms a class of compounds which have been called *amalgams*. These are generally brittle or soft. One part of potassium with 70 of mercury produce a hard brittle compound. If mercury be added to the liquid alloy of potassium and sodium (606), an instant solidification ensues, and heat enough to inflame the latter metals is evolved. The use of an amalgam of zinc and mercury has already been adverted to for the excitation of electrical machines. (108.) The amalgams of gold and silver are employed in gilding and plating.

An amalgam of 2 parts of mercury, 1 of bismuth, and 1 of lead, is fluid, and when kept for some time, deposits cubic crystals of bismuth.

Amalgam of copper may be made as follows: To a hot solution of sulphate of copper, add a little muriatic acid, and a few sticks of zinc, and boil the mixture for about a minute: by this means the copper will be precipitated in a metallic state, and in a finely divided spongy form: take out the zinc, pour off the liquor, wash the copper with hot water, and pour upon it a little dilute nitrate of mercury, which will instantly cover every particle of copper with a coating of mercury: then add mercury to the amount of two or three times the weight of the copper, and a slight trituration will combine them so far that the completion of the process may be effected by heating the mixture for a few minutes in a crucible.—AIKIN'S *Dictionary*, Art. *Mercury*, p. 92.

1189. When mercury is negatively electrized in a solution of ammonia, or when an amalgam of potassium and mercury is placed upon moistened muriate of ammonia, the metal increases in volume, and becomes of the consistency of butter, an appearance which has sometimes been called the *metallization of ammonia.* The compound appears only to contain ammonia and mercury, though its real nature has not been satisfactorily ascertained. It has suggested some hypotheses concerning the nature of ammonia and the metals, which are not worth recording.

SECTION XXX. *Osmium.*

1190. OSMIUM, and the metals described in the three following sections, are contained in the ore of platinum. This ore is digested in nitro-muriatic acid, by which the greater portion is dissolved, and there remains a black powder, which, when fused with potassa and washed, furnishes a yellow alcaline solution of oxide of osmium. Saturate the alcali with sulphuric acid, pour the mixture into a retort, and distil. A colourless solution of the *oxide of osmium* passes into the receiver; it has a sweetish taste and a very peculiar smell, somewhat like that of new bread. When mercury i shaken with this solution it becomes an amalgam, which is decomposed by distillation, and pure osmium remains.

1191. Osmium has a dark grey colour, and is not volatile when heated in close vessels: but heated in the air it absorbs oxygen, and forms a volatile oxide. It has not been fused.

1192. The leading characters of osmium are its insolubility in the acids, its ready solubility in potassa, the facility with which it is oxidized, the singular smell of its oxide, its great volatility, and the purple or blue colour produced in its solution by tincture of galls. The other compounds have scarcely been examined.

SECTION XXXI. *Iridium.*

1193. THE black powder mentioned in the last section contains iridium, which resists the action of potassa, and consequently remains after the separation of osmium. A solution of its oxide may be procured by digesting it in muriatic acid, which first becomes blue, then olive-green, and, lastly, red. By alternate treatment with potassa and muriatic acid, the whole of the black powder will be dissolved. By evaporating the muriatic solution to dryness, dissolving the dry mass in water, and evaporating a second time, octoëdral crystals of muriate of iridium are obtained.

1194. Iridium is obtained by immersing a plate of zinc into a solution of the muriate, or by violently heating the octoëdral crystals. It is of a whitish colour, and, according to Mr. Children, who succeeded in fusing it by means of his large Voltaic apparatus, its specific gravity is above 18. Its most marked character is extremely difficult solubility in the acids.

1195. In crude platinum Dr. Wollaston discovered some flat white grains which resisted the action of the acids, and which he ascertained to consist of *a native alloy of osmium and iridium.*

1196. Osmium and iridium were discovered by Mr. Tennant in 1803. The name of the former is derived from the peculiar smell of its oxide; that of the latter, from the variety of colours exhibited by its solution.—*Phil. Trans.*, 1804.

SECTION XXXII. *Rhodium.*

1197. RHODIUM and Palladium were discovered by Dr. Wollaston in 1803. These, like the two last-described metals, exist in the ore of platinum, from which rhodium may be obtained by the following process: Digest crude platinum in a small quantity of nitro-muriatic acid, filter the saturated solution, and pour it into a solution of sal ammoniac, by which the greater proportion of the platinum is precipitated. Decant the clear liquor and immerse a plate of zinc, which becomes coated with a black powder. Separate this and digest it in dilute nitric acid, by which a little copper and lead are taken up. Then wash and digest in dilute nitro-muriatic acid, to which add some common salt, evaporate to dryness, and wash the dry mass repeatedly with alcohol. A deep red substance remains, which, when dissolved in water, furnishes a black precipitate upon the immersion of a plate of zinc. This, strongly heated with borax, assumes a white metallic lustre, and is rhodium.

1198. Rhodium is very difficult of fusion; its specific gravity is 10.6. When an alloy of lead and rhodium is digested in nitro-muriatic acid, it is dissolved, and by evaporation a red compound is obtained, from which muriate of rhodium may be separated by water, or more perfectly by alcohol. The rose-colour of this compound suggested the name which has been applied to the metal.

1199. Rhodium forms malleable *alloys* with the malleable metals, several of which have been examined by Dr. Wollaston.—*Phil. Trans.*, 1804. THOMSON'S *System*, Vols. i. and ii.

With steel, rhodium forms an alloy, which probably would be very useful in the arts, were it not for the scarcity of the latter metal. 1 to 2 *per cent.* of rhodium gives steel great hardness, and yet there is sufficient tenacity to prevent cracking either in forging or hammering.—*Quarterly Journal*, ix. 328.

SECTION XXXIII. *Palladium.*

1200. PALLADIUM is most easily obtained by the following process. (WOLLASTON, *Phil. Trans.*, 1805.) Digest the ore of platinum in nitro-muriatic acid, neutralize the redundant acid by soda, throw down the platinum by muriate of ammonia, and filter. To the filtered liquor add a solution of cyanuret of mercury (1178); a yellow flocculent precipitate is soon deposited which yields palladium on exposure to heat.

1201. Palladium is of a dull white colour, malleable and ductile. Its specific gravity is about 11. It is hard. It fuses at a temperature above that required for the fusion of gold.

1202. Dr. Wollaston has ascertained the existence of *native palladium* in the ore of platinum. It is in small fibrous grains.

1203. Muriatic acid boiled upon palladium acquires a fine red colour. Sulphuric acid becomes blue. Nitric acid readily dissolves it; but its best solvent is the nitro-muriatic, which forms a fine red solution. The alcalis throw down an orange-coloured precipitate from these solutions, sparingly soluble in the alcalis. Ferrocyanate of potassa gives an olive-green precipitate; and sulphuretted hydrogen, one of a dark brown colour.

SECTION XXXIV. *Silver.*

1204. SILVER is found native, and in a variety of combinations.

Native Silver has the general characters of the pure metal. It occurs in masses; arborescent; capillary; and, sometimes, crystallized in cubes and octoëdra. It is seldom pure, but contains small portions of other metals, which affect its colour and ductility. It is chiefly found in primitive countries. In Peru and Mexico are the richest known mines of native silver. The mines of Saxony, Bohemia, and Swabia, and those of Kongsberg in Norway, are the richest in Europe. It has been found in Cornwall and Devonshire.

1205. Pure silver may be procured by dissolving the standard silver of commerce in pure nitric acid, diluted with an equal measure of water. Immerse a plate of clean copper into the solution, which soon occasions a precipitate of metallic silver; collect it upon a filter; wash it with solution of ammonia, and then with water, and fuse it into a button.

It may also be procured by adding to the above solution of standard silver a solution of common salt; collect, wash, and dry the precipitate, and fuse it with its weight of carbonate of potassa. A button of the pure metal is thus obtained.

1206. Silver has a pure white colour, and considerable brilliancy. Its specific gravity is 10.5. It is so malleable and ductile, that it may be extended into leaves not exceeding a ten-thousandth of an inch in thickness, and drawn into wire finer than a human hair.

1207. Silver melts at a bright red heat, and when in fusion appears extremely brilliant. It resists the action of air at high temperatures for a long time, and does not oxidize; the *tarnish* of silver is occasioned by sulphureous vapours; it takes place very slowly upon the pure metal, but more rapidly upon the alloy with copper used for plate, and was found by Proust to consist of sulphuret of silver. Pure water has no effect upon the metal; but if the water contain vegetable or animal matter, it often slightly blackens its surface in consequence of the presence of sulphur. If an electric explosion be passed through fine silver wire, it burns into a black powder, which is an oxide of silver. In the Voltaic circle it burns with a fine green light, and throws off abundant fumes of oxide. Exposed to an intense white heat, it boils and evaporates. If suddenly cooled, it crystallizes during congelation, often shooting out like a cauliflower, and throwing small particles of the metal out of the crucible.

1208. Silver is not unfrequently obtained in considerable quantities from argentiferous sulphuret of lead, which is reduced in the usual way and then *cupelled:* the oxide of lead thus procured is afterwards reduced by charcoal.

Some of the silver ores, especially the sulphurets, are reduced by amalgamation. These ores, when washed and ground, are mixed with a portion of common salt and roasted; it is then powdered and mixed by agitation with mercury, and the amalgam thus formed is distilled.

The old process of *eliquation* is now scarcely used: it consisted in fusing alloys of copper and silver with lead; this triple alloy was cast into round masses, which were set in a proper furnace upon an inclined plane of iron with a small channel grooved out, and heated red-hot, during which the lead melted out, and, in consequence of its attraction for silver, carried that metal with it, the copper being left behind in a reddish black spongy mass.—AIKIN'S *Dictionary*, Art. SILVER.

1209. *Oxide of Silver* may be obtained by adding lime-water to the solution of nitrate of silver, and washing the precipitate. It is of a dark olive colour, tasteless, insoluble in water, and when gently heated, is reduced to the metallic state.

The composition of oxide of silver has been very variously given, probably from the difficulty of obtaining it of similar purity. If its composition be inferred from the chloride, or from the sulphuret, we obtain the number 102.5 as the representative of silver, and the oxide will consist of

102.5	silver
7.5	oxygen
110.	oxide of silver.

By a direct experiment upon the oxide of silver, precipitated by potassa from the nitrate, it is found that 40 grains gave 7.9 cubical inches of oxygen, and 36.4 grains of silver remained; the 7.9 cubic inches would weigh 2.686 grains, and

Oxygen.		Silver.		Oxygen.		Silver.
2.686	:	36.4	::	7.5	:	101.6.

I have preferred the number 102.5 as being deduced from the chloride, which is a more uniform compound than the oxide.

1210. Mr. Faraday has rendered it probable that there is another combination of silver and oxygen, containing a smaller proportion of oxygen than the above, but it is not capable of combining with the acids.

1211. Oxide of silver readily dissolves in ammonia, and by particular management, a *fulminating silver*, composed of the oxide combined with ammonia, may be obtained. It was discovered by Berthollet, (*Annales de Chimie*, Tom. i.) The best process for obtaining it is to pour a small quantity of liquid ammonia upon the oxide; a portion is dissolved, and a black powder remains, which is the detonating compound. It explodes when gently heated; nitrogen and water are instantaneously evolved, and the silver is reduced. The oxide of silver should be perfectly pure and thoroughly edulcorated, and the ammonia quite free from carbonic acid. It should only be prepared in small quantities, and handled with the greatest caution, many accidents having arisen from its careless management. It sometimes explodes while still wet.

1212. *Silver and Chlorine—Chloride of Silver.*—This compound is easily procured by adding a solution of chlorine, of muriatic acid, or of common salt, to a solution of nitrate of silver: it falls in the form of a heavy insoluble tasteless powder, of a white colour, but which, by exposure to light, becomes brown, and ultimately black. When dry chloride of silver is heated to dull redness in a silver crucible it does not lose weight, but fuses; and, on cooling, concretes into a grey semi-transparent substance, which has been called *horn silver*, or *luna cornea.* If slowly cooled, Proust has remarked that it has a tendency to octoëdral crystallization. Heated to a bright red or white heat in an open vessel, it volatilizes in dense white fumes.

1213. If fused with twice its weight of potassa or soda, chloride of silver is decomposed, and a globule of metallic silver is obtained. It is also rapidly decomposed by tin and zinc. Triturated with zinc filings and moistened, the heat produced is so considerable as to fuse the resulting alloy of zinc and silver.—FARADAY, *Quarterly Journal of Science and Arts*, viii. 374.

1214. Chloride of silver is very soluble in ammonia, a circumstance by which it is usefully distinguished from some other chlorides, which, like it, are white, and formed by precipitation. We should be cautious in applying heat to the ammoniacal solution, as it sometimes forms a precipitate of fulminating silver. The ammoniacal solution furnishes crystals, which, when exposed to air, or put into water, lose their transparency, ammonia is evolved, and they crumble into chloride of silver. The fused chloride, exposed to ammoniacal gas, absorbs a considerable portion, which is given off by heat. If the dry chloride, thus saturated with ammonia, be thrown into chlorine, the ammonia spontaneously inflames. (FARADAY, *Journal of Science and Arts*, Vol. v., p. 75.) Chloride of silver is soluble in and decomposed by all the liquid hyposulphites.

1215. As chloride of silver is insoluble in water, and very readily formed, it is often employed in analysis, as a means of ascertaining the proportion of chlorine present in various compounds. In these cases some excess of the precipitant should be used, and the precipitate allowed to subside previous to separating it upon the filter: if the supernatant liquor become perfectly clear, the whole of the silver has fallen; if it remain opalescent, a portion is probably still retained. The chloride in these cases should be perfectly dried in a silver crucible, up to incipient fusion.

1216. The following are three of the best analyses of chloride of silver, and their close correspondence is no small test of their accuracy.

	Marcet.	Gay-Lussac.	John Davy.
Silver . .	75.47	75.25	75.5
Chlorine	24.53	24.75	24.5
	100.00	100.00	100.0

The mean composition deduced from these experiments may be called

Silver......	75.4
Chlorine....	24.6
	100.

And we may accordingly, without material error, consider the chloride of silver as composed of

1 prop^l. of silver	= 102.5	
1 ——— chlorine	= 33.5	
	136.	chloride of silver.

1217. *Native Chloride of Silver* has been found in most of the silver mines; it occurs massive and crystallized in small cubes.

1218. *Chlorate of Silver* is formed by digesting oxide of silver in chloric acid: it forms small rhombic crystals, which by the action of chlorine are converted into chloride of silver.

1219. Muriatic acid has no action upon a piece of clean silver, unless boiled with it for a long time, when a slight crust of chloride forms upon it. A beautiful experiment, illustrating the influence of electricity on chemical action, consists in attaching a slip of silver to one of zinc, and putting the double bar into dilute muriatic acid; the silver instantly acquires a crust of chloride in consequence of the negative energy imparted to it by the zinc, the latter metal being rapidly dissolved.

1220. *Iodide of Silver* is precipitated upon adding hydriodic acid to a solution of nitrate of silver. It is of a greenish yellow colour, insoluble, and decomposed when heated with potassa. It is particularly characterized by insolubility in ammonia.

1221. *Iodate of Silver* is precipitated in the form of a white powder by adding iodic acid or iodate of potassa to a solution of nitrate of silver. It is very soluble in ammonia.

1222. *Nitrate of Silver.*—Nitric acid, diluted with three parts of water, readily dissolves silver, with the disengagement of nitric oxide gas. If the acid contain the least portion of muriatic, the solution will be turbid, and deposit a white powder; and if the silver contain copper, it will have a permanent greenish hue; or if gold, that metal will remain undissolved in the form of a black powder.

The solution should be perfectly clear and colourless; it is caustic, and tinges animal substances of a deep yellow, which, by exposure to light, becomes a deep purple, or black stain, and is indelible, or peels off with the cuticle: it consists of reduced silver. It may be obtained in white crystals, in the form of four and six-sided tables, of a bitter and metallic taste, and soluble in about their own weight of water at 60°. It blackens when exposed to light, and when thus acted upon, is no longer perfectly soluble in water, owing to the separation of a portion of metallic silver.

1223. When heated in a silver crucible it fuses, and if cast into small cylinders, forms the *lapis infernalis*, or *lunar caustic* of pharmacy; the *argenti nitras* of the *Pharmacopœia*. In forming this preparation, care should be taken not to overheat the salt, and the moulds should be warmed. Exposed to a red heat, the acid is partly evolved and partly decomposed, and metallic silver obtained.

1224. Sulphur, phosphorus, charcoal, hydrogen, and several of the metals, decompose this nitrate. A few grains mixed with a little sulphur, and struck upon an anvil with a heavy hammer, produce a detonation; phosphorus occasions a violent explosion when about half a grain of it is placed upon a crystal of the nitrate, upon an anvil, and struck sharply with a hammer; and if heated with charcoal, it deflagrates, and the metal is reduced.

If a piece of silk dipped into a solution of nitrate of silver be exposed while moist to a current of hydrogen gas, it is first blackened, and afterwards becomes iridescent from the reduction of portions of the metal.—Mrs. Fulhame's *Essay on Combustion.*

A stick of phosphorus, introduced into a solution of nitrate of silver, soon becomes beautifully incrusted with the metal, which separates upon it in arborescent crystals. A plate of copper occasions a brilliant precipitation of silver, and the copper is oxidized and dissolved by the acid.

1225. Mercury introduced into the solution of nitrate of silver, causes a beautiful crystalline deposit of silver, called the *arbor Dianæ:* it was first remarked by Lemery. To obtain this crystallization in its most perfect state, the solution should contain a little mercury, and the mercury put into it should be alloyed with a little silver. Baumé directs an amalgam of one part of silver with seven of mercury, of which a small piece is to be introduced into a solution composed of six drachms of saturated nitrate of silver and four drachms of a similar solution of mercury diluted with five ounces of distilled water: a small flask or matrass should be used for the experiment, kept perfectly at rest: in a few minutes small filaments of silver darken the surface of the amalgam, and in about eight and forty hours the whole has separated in a shrub-like form. The principal use of the addition of mercury to the solution, and of silver to the precipitating mercury, is to give a degree of tenacity to the arborescent deposit of crystals, which prevents their falling to the bottom of the flask.

1226. The alcaline metallic oxides decompose this salt of silver: it is also decomposed by muriatic, sulphuric, phosphoric, and boracic acid. The protosulphate of iron throws down metallic silver when added to a solution of the nitrate: protomuriate of tin forms a grey precipitate consisting of peroxide of tin and oxide of silver.

1227. Ammonia added to solution of nitrate of silver occasions a precipitate soluble in excess of the alcali.

1228. Nitrate of silver is of much use, as a test for chlorine, muriatic acid, and their compounds. It is employed for writing upon linen under the name of *indelible* or *marking ink*, and is an ingredient in many of the liquids which are sold for the purpose of changing the colour of hair. It is used in medicine and surgery.

1229. *Nitrite of Silver* is obtained, according to Proust, by long digestion of powdered silver in nitric acid already saturated with the metal. It is more soluble than the nitrate, and difficultly crystallizable. It appears not improbable that this salt may contain the suboxide noticed by Mr. Faraday. (1210.)

1230. *Sulphuret of Silver.*—Silver readily combines with sulphur, and produces a grey crystallizable compound, considerably more fusible than silver. It is this which forms the *tarnish* upon silver plate. (1207) It consists of 1 proportional of each of its components.

Silver..	102.5	
Sulphur	15	
	117.5	sulphuret of silver.

1231. Sulphuretted hydrogen and hydrosulphuret of ammonia occasion a copious black precipitate of sulphuret of silver when added to solutions of the metal; a portion of the silver is frequently at the same time reduced to the metallic state.

1232. *Native Sulphuret of Silver,* or *vitreous silver ore,* is found in various forms, and when crystallized, is in cubes, octoëdra, and dodecaëdra. It is soft and sectile. The finest specimens are from Siberia.

1233. A triple combination of silver and antimony with sulphur, constitutes the *red* or *ruby silver ore;* it is found massive and crystallized in hexaëdral prisms. It consists of about 70 parts of sulphuret of silver, and 30 sulphuret of antimony. It occurs in all the silver mines, and is sometimes accompanied by the *brittle sulphuret of silver*, or *silver glance.*

1234. *Hyposulphite of Silver* has been examined by Mr. Herschel in his able paper on the hyposulphurous acid (*Edin. Phil. Journal,* i. 26.) It is formed by dropping a weak solution of nitrate of silver into a very dilute solution of hyposulphite of soda; a white cloud is at first produced, which re-dissolves on agitation; on adding more of the precipitant, the cloud re-appears and aggregates into a grey precipitate, which appears to consist of hyposulphite of silver; the supernatant liquor tastes intensely sweet, which is remarkable considering the disgusting bitterness both of the nitrate and of the hyposulphite, and shows, says Mr. Herschel, " how little we know of the way in which bodies affect the organs of taste. Sweetness and bitterness, like acidity, seem to depend upon no particular principle, but to be regulated by the state of combination in which the same principles exist at different times."

Hyposulphite of silver is also produced when chloride of silver is dissolved in any of the hyposulphites; the solution is intensely sweet without any metallic flavour.

1235. *Hyposulphite of Potassa and Silver* is formed when liquid potassa is dropped into the solution of chloride of silver in hyposulphite of soda; it separates in the form of a copious precipitate, which, when washed and dried, is found to consist of small grey pearly scales; they are difficultly soluble in water; of a very sweet taste; and heated before the blow-pipe afford a bead of silver.

1236. *Sulphite of Silver* is obtained in crystalline grains by digesting oxide of silver in sulphurous acid.

1237. *Sulphate of Silver* is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver in sulphuric acid. It requires about 90 parts of water at 60° for its solution; in boiling water it is more soluble and is deposited, as the solution cools, in small prismatic crystals: it is decomposed at a red heat. It consists of

1 prop^l. of oxide of silver	=	110
1 ——— sulphuric acid	=	37.5
		147.5 sulphate of silver.

1238. A compound acid, which may be called *nitro-sulphuric*, consisting of one part of nitre dissolved in about ten of sulphuric acid, dissolves silver at a temperature below 200°, and the solution admits of moderate dilution before sulphate of silver separates from it. This acid scarcely acts upon copper, lead, or iron, unless diluted with water; it is, therefore, useful in separating the silver from old plated articles: the precious metal may afterwards be separated either in the form of chloride, by adding common salt; or by diluting the acid and continuing the immersion of the pieces of copper which have lost their silvering, and which will now dissolve in the diluted acid and occasion the precipitation of metallic silver.—KEIR, *Phil. Trans.*, lxxx.

1239. *Phosphuret of Silver* is a white brittle compound.

1240. Neither *Hypophosphite* nor *Phosphite of Silver* have been examined.

1241. *Phosphate of Silver* is formed by dropping a solution of phosphate of soda into nitrate of silver. It is of a yellow colour, and consists, according to Berzelius, (*Annales de Chimie et Physique*, Tom. ii.) of

83	oxide of silver
17	phosphoric acid
100	

so that it may be considered as a compound of 1 proportional of oxide of silver = 110 + 1 proportional of phosphoric acid = 26.

1242. *Carbonate of Silver* is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light. It consists of

1 proportional of carbonic acid = 20.7
1 ———————— oxide of silver = 110
Carbonate of silver = 130.7

1243. Carbonate of ammonia only throws down a portion of the silver from the nitrate, and forms a triple *ammonio-carbonate of silver*.

1244. *Borate of Silver* is thrown down from the nitrate of silver in the form of white powder, by adding solution of borate of soda.

1245. Hydrocyanic acid and hydrocyanate of potassa cause a white precipitate in solutions of silver, which appears to be a cyanuret of silver, and which, when heated, gives out cyanogen.

1246. *Arsenite of Silver* is precipitated in the form of a white powder, soon becoming yellow and brown, by the addition of solution of arsenious acid to nitrate of silver.

1247. *Arseniate of Silver* is thrown down from nitrate of silver by arsenic acid, of a reddish brown colour.

1248. *Molybdate of Silver* has not been examined.

1249. *Chromate of Silver* is precipitated of a crimson colour by adding chromate of soda to nitrate of silver. It soon loses its brilliant tint and becomes brown.

1250. *Tungstate of Silver*—not examined.

1251. The soluble salts of silver are recognised by furnishing a white precipitate with muriatic acid, which blackens by exposure to light, and which is readily soluble in ammonia; and by affording metallic silver upon the immersion of a plate of copper. The salts insoluble in water are soluble in liquid ammonia, and when heated on charcoal before the blowpipe they afford a globule of silver.

1252. *Alloys of Silver.*—The compounds of this metal with potassium, sodium, and manganese, have not been examined. It unites difficultly with iron.

1253. When silver and steel are fused together, an alloy is formed, which appears perfect while in fusion, but globules of silver exude from it on cooling, which shows the weak attraction of the metals. At a very high temperature the greater part of the silver evaporates, but a portion equal to about 1 in 500 remains, forming a perfect alloy, admirably adapted to the formation of cutting instruments.—STODART and FARADAY, on the Alloys of Steel. *Quarterly Journal*, ix.

1254. Silver readily combines with zinc and tin, forming brittle alloys. The alloy of silver with copper is of the most importance, as it constitutes plate and coin. By the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous, while its colour is scarcely impaired.

The *standard silver* of this country consists of $11\frac{2}{20}$ pure silver and $\frac{18}{20}$ copper. A pound troy, therefore, is composed of 11 oz. 2 dwts. pure silver, and 18 dwts. of copper, and it is coined into 66 shillings. With lead the alloy is grey and brittle, as also with antimony, bismuth, cobalt, and arsenic.

1255. Amalgam of silver is sometimes employed for *plating;* it is applied to the surface of copper, and the mercury being evaporated by heat, the remaining silver is burnished. The better kind of plating, however, is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

1256. A mixture of chloride of silver, chalk, and pearlash, is employed for silvering brass: the metal is rendered very clean, and the above mixture, moistened with water, rubbed upon its surface. In this way thermometer scales and clock dials are usually silvered.

1257. The analysis of alloyed silver is a very important process, and in continual practice by refiners and assayers. It may be performed in the humid way by dissolving the alloy in nitric acid, precipitating with muriatic acid, and either reducing the chloride by potassa in the way above described (1213), or estimating the quantity of silver which it contains. The usual method, however, which is employed at the mint, and by the refiners, is *cupellation.*

1258. Of the useful metals, there are three only which are capable of resisting the action of air at high temperatures; these are silver, gold, and platinum; the others, under the same circumstances, become oxidized; it might, therefore, be supposed, that an alloy, containing one or more of the former metals, would suffer decomposition by mere exposure to heat and air, and that the oxidable metal would burn away. This, however, is not the case; for if the proportion of the latter be small, it is protected, as it were, by the former; or, in other cases, a film of oxide coats the fused globule, and prevents the further action of the air. These difficulties are overcome by adding to the alloy some highly oxidable metal, the oxide of which is fusible. Lead is the metal usually selected for this purpose, though bismuth will also answer. Supposing, therefore, that an alloy of silver and copper is to be *assayed*, or analyzed by cupellation: the following is the mode of proceeding.

A clean piece of the metal, weighing about 30 grains, is laminated, and accurately weighed in a very sensible balance. It is then wrapped up in the requisite quantity of sheet lead, (pure and reduced from litharge,) and placed upon a small *cupel*, or shallow crucible, made of bone earth, which has been previously heated. The whole is then placed under the muffle, heated to bright redness; the metals melt, and by the action of the air which plays over the hot surface, the lead and copper are oxidized and absorbed by the cupel, and a button of pure silver ultimately remains, the completion of the process being judged of by the cessation of the oxidation and motion upon the surface of the globule, and by the very brilliant appearance assumed by the silver when the oxidation of its alloy ceases. The button of pure metal is then suffered to cool gradually, and its loss of weight will be equivalent to the weight of the alloy, which has been separated by oxidation.

To perform this process with accuracy, many precautions are requisite, and nothing but practice can teach these, so as to enable the operator to gain certain results. An excellent article upon the subject will be found in AIKIN'S *Chemical Dictionary*, and in Mr. CHILDREN'S *Translation of* THENARD *on Chemical Analysis.*

SECTION XXXV. *Gold.*

1259. GOLD occurs in nature in a metallic state, alloyed with a little silver or copper, and in this state is called *native gold.* Its colour is various shades of yellow; its forms are massive, ramose, and crystallized in cubes and octoëdra. The veins of gold are confined to primitive countries, but large quantities of this metal are collected in alluvial soils and in the beds of certain rivers, more especially those of the west coast of Africa, and of Peru, Brazil, and Mexico. In Europe, the streams of Hungary and Transylvania have afforded a respectable quantity of gold; it has been found also in the Rhine, the Rhone, and the Danube. Small quantities have been collected in Cornwall, and in the county of Wicklow in Ireland.

1260. Gold may be obtained pure by dissolving standard gold in nitro-muriatic acid, evaporating the solution to dryness, re-dissolving the dry mass in distilled water, filtering, and adding to it a solution of protosulphate of iron; a black powder falls, which, after having been washed with dilute muriatic acid and distilled water, affords on fusion a button of pure gold.

1261. Gold is of a deep yellow colour. It melts at a bright red heat, and when in fusion appears of a brilliant green colour.

Gold is so malleable that it may be extended into leaves which do not exceed $\frac{1}{28000}$ of an inch in thickness. It is also very ductile. It shows no tendency to unite to oxygen when exposed to its action in a state of fusion; but if an electric discharge be passed through a very fine wire of gold, a purple powder is produced, which has been considered as an oxide.

1262. *Oxide of Gold* may be obtained by adding a solution of potassa to a solution of muriate of gold, and heating the mixture; the precipitate must be washed first with weak solution of potassa, and then with water, and dried at a temperature of 100°; if the heat exceed this, a portion of the oxide is reduced, and it is then only partially soluble in muriatic acid. If this be regarded as a protoxide, that is, as consisting of 1 proportional of gold + 1 of oxygen, then the number 97 will represent gold, and this oxide will consist of 97 gold + 7.5 oxygen = 104.5*. It is, however, probable that the purple powder produced by the combustion of gold contains a portion of oxygen.

1263. *Chloride of Gold.*—When gold in a state of minute division is heated in chlorine, a compound of a deep yellow colour results, which is said to consist of 97 gold + 33.5 chlorine. When acted upon by water, a *muriate of gold* is produced.

1264. The action of *iodine* on gold has been examined by M. Pelletier, (*Quarterly Journal of Science and Arts*, x. 121.) When hydriodate of potassa is added to muriate of gold, it produces a very copious yellowish brown precipitate, insoluble in cold water, and easily decomposed by heat. It gave on analysis

Iodine........	34
Gold.........	66

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* These numbers are deduced from Proust's experiments.—Nicholson's *Journal*, Vol. xiv.

If this be considered a compound of 1 proportional gold and 1 of iodine, the number 228 must be adopted as the representative of gold, for 34 : 66 :: 117.7 : 228.3, a number so much at variance with that deduced from other experiments, as to show the necessity of further inquiries, before either be adopted.

1265. *Nitrate of Gold.*—The nitric acid has scarcely any action upon gold, but it readily dissolves the oxide, forming a yellow styptic deliquescent salt.

1266. The true solvents of gold are solution of chlorine and nitro-muriatic acid; the latter is usually employed, composed of two parts of muriatic and one of nitric acid. By evaporation, the saturated solution, which, however, is always acid, affords prismatic crystals of *muriate of gold.* This salt is very deliquescent; it is decomposed by heat, leaving a spungy mass of pure gold; a very minute portion of the metal also passes off with the muriatic acid.

1267. When potassa is added to the solution of muriate of gold, no precipitate occurs till heat is applied, when a reddish-yellow precipitate falls, which is peroxide of gold (1262); the whole of the metal, however, is not thrown down, a portion being retained so as to form a *triple muriate of gold and potassa,* which is very soluble and not decomposed by further excess of alcali: it is on this account that a very acid solution of muriate of gold will afford no precipitate whatever with potassa or soda, the triple salt formed being in that case sufficient to employ the whole of the oxide of gold. M. Pelletier has stated that potassa alone dissolves oxide of gold, and has called the compound *aurate of potassa.*

1268. When liquid ammonia is added to a concentrated solution of muriate of gold diluted with about three parts of water, a yellowish-brown precipitate is formed, which if collected upon a filter, washed with a little water, and carefully dried at the temperature of 212°, is *fulminating gold.* Bergman first showed that this compound consists of about five parts of peroxide of gold and one of ammonia: when heated to about 400°, it explodes violently, the gold is reduced, and nitrogen and water are evolved; hence it appears that the ammonia is decomposed, that its hydrogen uniting with the oxygen of the oxide forms water, and that the nitrogen is suddenly liberated. It explodes by friction with hard bodies, and by an electrical shock. If two or three grains be detonated upon a thin piece of platinum leaf, the metal is torn at the point of contact.

1269. Muriate of gold is decomposed by phosphorus and charcoal, and by sulphurous acid: a piece of paper, moistened with it and exposed to light, also becomes purple in consequence of its decomposition.

1270. When solution of protosulphate of iron is added to muriate of gold, the mixture instantly acquires a dingy green or brown tinge, and appears of a beautiful green if viewed by strong transmitted light: these appearances depend upon the presence of an infinite number of small particles of gold in the metallic state, its oxygen having been imparted to the salt of iron: they soon subside in the form of a brown powder, which may be collected upon a filter and fused into a button. This method of separating gold from its solution is often convenient in analytical operations.

1271. Protomuriate of tin, added to muriate of gold, occasions an instant change of colour to a reddish brown or dirty purple: if a piece of tin foil be immersed in a dilute solution of the muriate of gold, the same purple powder is presently thrown down upon it: this powder is used in enamel painting, and for tinging glass of a fine red colour, under the name of *purple of Cassius:* it is a compound of peroxide of tin and oxide of gold, the latter metal appearing to be in a very low state of oxidizement, and yet soluble in muriatic acid: it is also soluble in ammonia, forming a deep purple liquor. It would appear from Proust's experiments to consist of about three parts oxide of tin, and one of oxide of gold.

1272. If a solution of muriate of gold be mixed with sulphuric ether it combines with the oxide, and an *ethereal solution of gold* is obtained. Polished steel dipped into this solution acquires a coat of gold, and it has hence been employed for gilding delicate cutting instruments. (See *Sulphuric Ether.*)

1273. *Sulphuret of Gold* is procured by passing sulphuretted hydrogen through an aqueous solution of muriate of gold. It is a black substance consisting probably of 97 gold + 30 sulphur.—OBERKAMPF, *Annales de Chimie,* Tom. lxxx.

1274. *Sulphate of Gold* is formed by digesting the oxide in dilute sulphuric acid, but the salt has not been examined.

1275. *Phosphuret of Gold* is obtained by heating gold leaf with phosphorus, in a tube deprived of air. It is a grey substance of a metallic lustre, and consists probably of 97 gold + 11 phosphorus.

1276. *Alloys of Gold.*—A very curious detail of an extended and accurate series of experiments upon the alloys of gold has been published in the *Philosophical Transactions* for 1803, by Mr. Hatchett: his experiments were generally made with 11 parts of gold and 1 of alloy; or 38 grains of alloy to the ounce of gold.

1277. The alloys of gold with potassium, sodium, and manganese, have not been examined. With iron the alloy is malleable and ductile, and harder than gold, its colour dull white, and its specific gravity 16.885. The metals expand by union, so that supposing their bulk before combination to have been 1000, after combination it is 1014.7.

1278. With zinc the compound is brittle and brass-coloured. Specific gravity 16.937. The metals contract a little in uniting, the original bulk being 1000, that of the alloy is 997. The brittleness continued when the zinc was reduced to $\frac{1}{60}$ of the alloy. The fumes of zinc in a furnace containing fused gold, make it brittle.

1279. Tin formed a whitish alloy, brittle when thick, but flexible in thin pieces. Specific gravity 17.307. Bulk before fusion 1000; after fusion 981. So that there is considerable contraction. The old chemists called tin *diabolus metallorum*, from its property of rendering gold brittle, but Mr. Bingley's experiments quoted by Mr. Hatchett, show that $\frac{1}{60}$ of tin does not render gold brittle.

1280. The alloy of lead is very brittle when that metal only constitutes $\frac{1}{1920}$ of the alloy; even the fumes of lead destroy the ductility of gold. The specific gravity is 18.080; and 1000 parts become 1005. A very remarkable fact in respect to this alloy is, that its specific gravity diminishes, to a certain extent, as the proportion of lead diminishes, and is at its maximum when the lead amounts only to $\frac{1}{960}$th part, the quantity of gold remaining the same, and the deficiency being made up with copper. The following Table, drawn up by Mr. Hatchett, exhibits this remarkable fact :

METALS.	Grains.	Sp. Gravity of Alloy.	Bulk before Union.	Bulk after Union.	Expansion.
Gold...... Lead......	442 38	18.080	1000	1005	5
Gold...... Copper.... Lead......	442 19 19	17.765	1000	1005	6
Gold...... Copper.... Lead......	442 30 8	17.312	1000	1022	22
Gold...... Copper.... Lead......	442 34 4	17.032	1000	1035	35
Gold...... Copper.... Lead......	442 37.5 0.5	16.627	1000	1057	57
Gold...... Copper.... Lead......	442 37.75 0.75	17.039	1000	1031	31

1281. The alloy with nickel was of a brass colour and brittle. The specific gravity of the gold being 19.172, and of the nickel 7.8, that of the alloy was 17.068. An expansion had taken place, 1000 parts before fusion having become 1007.

1282. With cobalt the alloy was very brittle. Specific gravity 17.112. 1000 parts became 1001 after fusion.

1283. With bismuth the alloy was of a brass colour, very brittle, and of a specific gravity = 18.038. 1000 parts became 988 after fusion, so that the condensation was considerable. When the bismuth amounted only to $\frac{1}{1920}$th part, the alloy was still brittle, though the colour was nearly that of gold.

1284. With copper (standard gold) the alloy is perfectly ductile and malleable, but harder than pure gold, and resists wear better than any other alloy except that with silver. Its specific gravity is 17.157. Gold coin is an alloy of eleven parts of gold and one of copper; of this alloy, twenty troy pounds are coined into 934 sovereigns and one half-sovereign; one pound formerly was coined into 44½ guineas; it now produces $46\frac{29}{40}$ sovereigns.

1285. Arsenic and antimony, when alloyed in very small proportions with gold, destroy its colour and render it quite brittle.

1286. The analysis of most of the alloys of gold is performed by cupellation. The triple alloy of gold, silver, and copper, may be analyzed by digesting it in nitric acid, which takes up the silver and copper, and leaves the gold in the form of a black powder, which may be fused into a button, and weighed. The silver may be thrown down in the state of chloride by solution of common salt, and the copper precipitated by iron.

1287. The assay of gold is more complicated than that of silver, in consequence of the high attraction which it has for copper, and which prevents its complete separation by mere cupellation. An alloy, therefore, of copper with gold, is combined with a certain quantity of silver, previous to cupellation; this is then cupelled with lead in the usual way, and the silver is afterwards separated by the action of nitric acid.

1288. The real quantity of gold or silver taken for an assay is very small; from 18 to 36 grains, for instance, for silver, and from 6 to 12 for gold; whatever the quantity may be it is called the *assay pound.* The silver assay pound is divided into 12 ounces, and each ounce into 20 penny-weights. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains.—AIKIN's *Dictionary.* *Art.* ASSAY.

1289. Mercury and gold combine with great ease, and produce a white amalgam much used in gilding. For this purpose the amalgam is applied to the surface of the silver; the mercury is then driven off by heat, and the gold remains adhering to the silver, and is burnished. This process is called *water gilding.*

In gilding porcelain *gold powder* is generally employed, obtained by the decomposition of the muriate; it is applied with a pencil, and burnished after it has been exposed to the heat of the porcelain furnace.

Many curious facts relating to the properties of gold, and its uses in the arts, will be found in Dr. LEWIS's *Philosophical Commerce of the Arts.*

SECTION XXXVI. *Platinum.*

1290. THIS metal is found in small grains in South America, confined to alluvial strata in New Granada. These grains, besides platinum, contain generally gold, iron, lead, palladium, rhodium, iridium, and osmium.

The pure metal may be obtained by dissolving crude platinum in nitro-muriatic acid, and precipitating by a solution of muriate of ammonia. This first precipitate is heated, dissolved in nitro-muriatic acid, and again precipitated as before. The second precipitate is heated white hot, and pure platinum remains. It is a white metal, extremely difficult of fusion, and unaltered by the joint action of heat and air. Its specific gravity is 21.5. It is very ductile, malleable, and tenacious.

1291. *Platinum and Oxygen.*—When nitrate of mercury is added to a dilute solution of muriate of platinum, a powder falls, which, when carefully heated, gives off calomel, and leaves a *black oxide of platinum,* composed, according to Mr. Cooper, of 100 platinum, + 4.5 oxygen.—*Journal of Science and the Arts,* Vol. iii.

Berzelius obtained an oxide of platinum by decomposing the muriate by sulphuric acid, and adding excess of potassa to the sulphate; a yellowish brown powder was obtained, which became nearly black on being dried, and consisted of 100 platinum + 16.4 oxygen.

(Thomson, Vol. i., p. 501.); but, according to Mr. Davy, the oxide, which is contained in the salts of platinum, consists of platinum 100, oxygen 11.8.

1292. *Chloride of Platinum* is obtained by evaporating the muriate and exposing it nearly to a red heat. Its colour is brown, and it is scarcely soluble in water. It gives off chlorine by a red heat. According to Mr. Edmund Davy, to whom we are principally indebted for our knowledge of the combinations of platinum, (*Phil. Mag.*, Vol. xl.) it consists of 100 platinum + 37.9 chlorine.

1293. Nitro-muriatic acid is the readiest solvent of platinum. The solution affords crystals which are very deliquescent and acrid; they are a *muriate of platinum.* The solution of this muriate is distinguished from all other metallic solutions by affording a precipitate upon the addition of muriate of ammonia, which is an *ammonio-muriate of platinum.* Ferrocyanate of potassa affords no precipitate. The addition of potassa occasions a precipitate of a triple compound of the alcali and muriate. Sulphuretted hydrogen occasions a black precipitate. Ether separates the oxide of platinum in the same way as that of gold. Muriate of tin occasions a very characteristic red precipitate in very dilute solution of platinum.

1294. There are, according to Mr. E. Davy, three *sulphurets of platinum.* The first, formed by heating the finely-divided metal with sulphur; the second, by precipitating nitro-muriate of platinum by sulphuretted hydrogen; and the third, by heating 3 parts of the ammonio-muriate with 2 of sulphur.

1295. According to the same authority there are two phosphurets. The first, obtained by heating phosphorus with the metal; the second, by heating phosphorus with the ammonio-muriate of platinum.

1296. The salts of platinum have been but little examined. Proust and Davy have described a *sulphate*, obtained by acidifying the sulphur in the sulphuret by means of nitric acid. It is of a brown colour, and very soluble; and with soda, potassa, and ammonia, it forms triple salts.

Mr. E. Davy found that the precipitate by a slight excess of ammonia, when boiled in potassa, washed and dried, was a *fulminating platinum*; it explodes at about 420°, with a very loud report, and appears to be a compound of oxide of platinum, ammonia, and water.—*Phil. Trans.*, 1817.

1297. A very singular compound of platinum is described by Mr. E. Davy, in the *Philosophical Transactions* (1820, p. 108), obtained by mixing equal volumes of strong aqueous solution of the sulphate and of alcohol. The colour of the sulphate slowly disappears, and in some days a black substance subsides, which is washed and dried. It is also formed by boiling the sulphate and alcohol together for a few minutes. This substance is permanent in the air and insoluble in water. It detonates feebly when heated, and is not affected by chlorine, nor by nitric, sulphuric, and phosphoric acids; but it is slowly soluble in muriatic acid. Put into liquid ammonia it acquires fulminating properties, and plunged into the gas it becomes red hot: the same phænomenon is exhibited by exposing it to the vapour of alcohol, or by placing it upon a piece of paper moistened with that fluid: in these cases the platinum is reduced with the evolution of heat, and the ignition seems to depend upon the slow combustion of the vapour of the alcohol, as has been elsewhere shown. (191.) From Mr. Davy's analysis of this compound, it appears to contain 96.25 platinum, 0.12 oxygen, 0.0106 carbon, 3.6194 nitric acid and water; the acid being derived from the mode of preparing the sulphate. (1296.)

1298. Experiments upon the composition of the various combinations of platinum are so entirely at variance with theory, that in the present state of our knowledge it is scarcely possible to deduce the number for platinum.

If the black oxide, described by Mr. Cooper, be considered as a protoxide, the number 176 will represent platinum, and the chloride (1292) will contain 1 proportional of platinum and 2 of chlorine. But the peroxide, the phosphurets, and the sulphurets, will not accord with this number.

1299. The alloys of platinum have not been applied to any useful purposes. By combining 7 parts of platinum with 16 of copper and 1 of zinc, Mr. Cooper obtained a mixture much resembling gold.—*Journal of Science and Arts*, Vol. iii., p. 119.

1300. Zinc, bismuth, tin, and arsenic, readily combine with platinum, and form fusible alloys. It also unites, though less readily, with copper, lead, and iron. It combines with gold, and unless there be great excess of the latter, the colour of the alloy resembles platinum.

1301. If a small piece of tin, zinc, or antimony, be rolled up in platinum leaf, and exposed to the jet of a blow-pipe, the two metals combine with such energy, when nearly white hot, as to produce a kind of explosion. Iron and steel also remarkably increase the fusibility of platinum.

1302. The alloys of steel and platinum have been examined by Stodart and Faraday. They combine in all proportions, but from 1 to 3 *per cent.* of platinum appears best adapted for cutting instruments. Equal weights of the two metals produce a fine hard and brilliant alloy, of a specific gravity of 9.862; it appears well adapted for mirrors, for it takes a fine polish and does not tarnish. An alloy of 90 platinum and 20 steel has a specific gravity of 15.88.

1303. Platinum has the property of being united by welding, either one piece to another, or with iron, or steel. Wires of steel, and platinum, when welded and polished, exhibit a curious and beautiful surface, especially when the steel parts are slightly acted upon by dilute acid. This welding property of platinum may be usefully applied in the arts; rings may be joined so as to form a chain, the durability of which must add to its value; and with a view to economy, platinum may be joined to iron or steel for many uses in the laboratory of the chemist.

SECTION XXXVII. *Silicium.*

1304. IT has been assumed that the earth silica consists of a metallic basis, united with oxygen, and that it contains 50 *per cent.* of each of its components; so that, if the earth be considered a deutoxide, it will consist of

$$\begin{array}{rl} 15 & \text{silicium} \\ 15 & \text{oxygen} \\ \hline 30 & \end{array}$$

This estimate of the composition of silica is deduced from the quantity of potassium which is required for its decomposition, but the subject requires farther elucidation.

1305. *Oxide of Silicium, Silica,* or *Siliceous Earth,* is a very abundant natural product. It exists pure in rock-crystal, and nearly pure in flint. It may be obtained by heating colourless rock-crystal to redness, quenching it in water, and reducing it to a fine powder; in this state it is silica almost perfectly pure. Fuse 1 part of this powder with 3 of potassa in a silver crucible. Dissolve the mass formed, in water, add slight excess of muriatic acid, and evaporate to dryness. Wash the dry mass in boiling distilled water upon a filter, and the white substance which remains is silica. This is the usual process, but the earth obtained by simply reducing the colourless rock crystal to powder, is more pure; for I have never been able to separate the last portions of alcali from silica precipitated from potassa.

1306. Silica is white; its specific gravity 2.66. It fuses at a very high temperature. In its ordinary state it is insoluble in water; but it dissolves in very minute portions in that fluid, when recently precipitated in the form of gelatinous hydrate; and in the same state it dissolves sparingly in the acids. It readily unites with the fixed alcalis, and forms *glass;* or, if the alcali be in excess, a liquid solution of the earth may be obtained (*liquor silicum*), from which it is precipitated in the state of a *gelatinous hydrate* by acids. This alcaline solution, after having been kept for several years, has formed small crystals of silica. I have seen in it a deposit much like calcedony, and as hard.

1307. *Glass* is essentially a compound of silica with fixed alcali, a variety of other substances being occasionally added for particular purposes, among which oxide of lead is perhaps the most important. The silica used in the manufacture of glass is of various degrees of purity; fine white sand is generally employed in this country; flints, and the white quartz pebbles, abundant in some rivers, are also occasionally used. The alcali is either potassa or soda; purified pearl-ash being preferred for fine glass; while less pure substances, such as wood-ash, barilla, and kelp, are used for common glass, where the impurities contained in those alcalis are of no importance. The alcali is always in the state of carbonate, but it loses its carbonic acid during combination with the silica; the quantity employed is about half the weight of the silica, but there is some loss during the process, by evaporation.

A glass composed solely of silica and alcali requires a very high temperature for its perfect fusion, and is very difficult to work, so that various substances are added, with the intention of forming a more fusible, colourless, dense, and transparent compound; oxide of lead, in the form of litharge or minium, is very efficacious in this respect; it increases the fusibility of the compound, gives it greater tenaciousness when red hot, increases its refractive power, and enables it to bear sudden changes of temperature. It is a copious ingredient in the *London flint glass*, celebrated for its brilliancy when cut, and used for most optical purposes. But lead, though it confers these advantages, is productive of some evil; it renders the glass so soft as easily to scratch, and so fusible that it softens at a dull red heat, a quality which, though sometimes desirable, is often disadvantageous in its chemical applications. It is also very difficult to obtain a mass of glass containing lead, of equal density throughout; it is generally wavy, a defect especially felt in selecting the object-glasses of telescopes.

Boracic acid and borax form an admirable flux for glass-making, but the expense of those materials confines them almost entirely to the manufacture of artificial gems.

Black oxide of manganese has long been used in glass-making; it was formerly called *glass soap*, a term implying its power of cleansing certain impurities, and especially the green tinge which is apt to arise from impure alcali; but if it be added at all in excess, it communicates a purple tinge, more or less intense according to its quantity. This purple hue is destroyed by charcoal, or by thrusting a billet of wood into the glass-pot, which causes a slight effervescence, and the colour disappears. There can be little doubt that the carbon acts by deoxidizing the manganese, for if a little nitre be added, the purple colour returns. Lime in very small quantities (8 or 10 parts of chalk to 100 of silica), is sometimes added to glass; it acts as a flux, but it endangers the transparency of the compound.

White arsenic is also used as a very cheap and powerful flux; and nitre, in small quantities, is employed to destroy any impurities arising from carbonaceous matter.

1308. The materials for the manufacture of glass are submitted to an operation called *fritting*, before they are transferred to the regular glass-furnace. It consists in exposing them to a dull red heat, by which moisture and carbonic acid are expelled, and a slight degree of chemical action induced; this also prevents the excessive swelling up of the materials in the glass-pots, and renders the process of vitrification more certain and expeditious.

The glass-pots are placed round a dome-shaped furnace, built upon arches, and open beneath for the free admission of air; there are generally six in each furnace, and they are entirely enclosed except at an orifice on the side, opening into a small recess formed by the alternate projections of the masonry and the flues, in which recess the workmen stand. Coal is the fuel employed, and the furnace is so built that a rapid current of flame may be directed round each glass-pot, which afterwards passes out with the smoke into the dome and chimney, heating a broad covered shelf in its passage, which is the annealing oven.

In the construction of the furnace and pots the greatest care is required ; especially in the latter, which have not only to resist long-continued heat, but also as far as possible, the action of ingredients which tend to accelerate their fusion or vitrification. They are usually made entirely of a refractory clay, one portion being crude or unburnt, and another calcined and powdered ; the latter being the remains of former furnaces when pulled down for repairs.

The frit is introduced into the glass-pots through the side-opening above-mentioned, and being heated to bright redness, becomes of a pasty consistency, and at length perfectly fuses. A quantity of impurities subside to the bottom of the pot, and partly rise to its surface. The scum, known under the name of *sandiver,* consists chiefly of saline substances, partly volatile at the high temperature of the furnace, which are removed from time to time, and sold to metal refiners as a powerful flux. The sandiver or *glass gall* being separated, the materials gradually become clearer, abundance of air-bubbles are extricated, and at length the glass appears uniform and complete ; the fire round the individual pot is then damped till its contents acquire a consistency fit for working, the whole process requiring about 48 hours from the time the pots are filled. At the working heat, which is a full red, the glass has a very peculiar tenacious consistency, and as it adheres but feebly to polished metal, it is easily wrought and managed with iron tools.

1309. All glass articles require to be carefully *annealed*, that is, suffered to cool very slowly, otherwise they are remarkably brittle and apt to crack, and even fly into many pieces upon the slightest touch of any hard substance, as is well shown in the small drops of green glass suddenly cooled by dropping it into water, and called *Rupert's drops;* the instant their thin end is broken off, they crumble into a powder with a kind of explosion. This phænomenon, according to Mr. Aikin, "depends upon some permanent and strong inequality of pressure, for when they are heated so red as to be soft, and merely let cool of themselves, the property of bursting is lost, and the specific gravity of the drop increased." What are termed *Bologna phials* are also made of unannealed glass, and fly to pieces when a piece of flint or other hard and angular substance is dropped into them.

1310. The exact composition of the different kinds of glass is scarcely known; the following proportions of the materials are, however, given in Messrs. Aikin's *Dictionary*, to which the reader is referred for a very valuable article upon the subject of glass, and from which I have abridged the preceding account.

Flint Glass. Specific gravity about 3.2.

120	parts of fine clear white sand
40	——— purified pearl-ash
35	——— litharge or minium
13	——— nitre

A small quantity of black oxide of manganese.

Crown Glass or best window glass.

200 parts of soda
300 ——— fine sand
33 ——— lime
250 ——— ground fragments of glass.

Green Bottle Glass.

100 parts of sand
30 ——— coarse kelp
160 ——— lixiviated earth of wood-ashes
30 ——— fresh wood-ash
80 ——— brick clay
100 ——— fragments of glass.

Plate Glass, invented by Abraham Thevart in 1688, was first manufactured in Paris. It may be composed of

300 lbs. fine sand
200 lbs. soda
30 lbs. lime
32 oz. manganese
3 oz. cobalt azure
300 lbs. fragments of good glass.

These materials are brought into perfect fusion, and poured upon a hot copper-plate, the mass is then rolled out, annealed, and afterwards polished by grinding with sand, emery, and colcothar. The difficulty of producing a perfect plate without specks, bubbles, or waves, may easily be conceived, and this, with the risk of breakage, renders a large plate extremely expensive.

1311. The art of *colouring glass*, and of making *artificial gems,* is of an old date, and effected by metallic oxides. The *paste* for artificial gems generally contains borax, and should be kept in fusion till perfectly clear. The following proportions are recommended by M. Douault-Wieland.—*Annales de Chim. et Phys.*, Tom. xix., 57.

	Grains.
Powdered rock-crystal	4056
Red lead	6300
Pure potassa	2154
Borax	276
Arsenic	12

M. Lançon gives the following as ingredients for a good paste:—

	Grains.
Litharge	100
White sand	75
White tartar or pot-ash	10

1312. The metals employed as colouring materials are: 1. Gold. The purple of Cassius imparts a fine ruby tint. 2. Silver. Oxide or phosphate of silver gives a yellow colour. 3. Iron. The oxides of iron produce green, yellow, and brown, depending upon the state of oxidizement and quantity. 4. Copper. The oxides of copper give a rich green; they also produce a red when mixed with a small proportion of tartar, which tends partially to reduce the oxide. 5. Antimony imparts a rich yellow. 6. Manganese. The black oxide of this metal, in large quantities, forms a black glass; in smaller quantities, various shades of purple.

7. Cobalt, in the state of oxide, gives beautiful blues of various shades; and with the yellow of antimony or lead it produces green. 8. Chrome produces fine greens and reds, depending upon its state of oxydizement.

The following are the best authorities upon the subject of coloured glasses and artificial gems:—NERI, *Art de la Verrerie.* KUNCKEL. FONTANIEU, *Encyclopédie Méthodique.* *Annales de Chim. et Phys.*, xiv., 57. AIKIN'S *Dictionary*, Art. GLASS.

1313. *White Enamel* is merely glass, rendered more or less milky or opaque by the addition of oxide of tin; it forms the basis of the coloured enamels, which are tinged with the metallic oxides.

1314. The only acid body which acts energetically upon silica is the hydrofluoric acid (618.) The result of this action is a gaseous compound, which has been called *silicated fluoric acid*, or *fluo-silicic acid;* it is probably a compound of silicium and fluorine.

1315. To obtain this gaseous compound, three parts of fluor spar, and one of silica finely powdered, are mixed in a retort with an equal weight of sulphuric acid; a gentle heat is applied, and the gas evolved is to be collected over mercury.

1316. Silicated fluoric acid is a colourless gas; its odour is acrid, much resembling muriatic acid; its taste very sour; its specific gravity 3.574 compared with air; 100 cubic inches weigh 110.78 grains, so that its specific gravity to hydrogen is 49.2. It extinguishes burning bodies. It produces white fumes when in contact with damp air; and when exposed to water, two compounds of silica with fluoric acid are formed; the one *acid,* and dissolved in the water; the other containing excess of silica, and insoluble. The dry compound contains 62 *per cent.* of silica; the aqueous solution only retains 55 *per cent.* Water dissolves 260 times its bulk of this gas.

1317. When one volume of silicated fluoric acid is mixed with two of ammonia, a total condensation ensues, and a dry *silico-fluate of ammonia* results.

1318. Potassium, when heated in this gas, burns and produces a brown compound, which, when dissolved in water, affords *hydrofluate of potassa.*

1319. It appears from the experiments of Mr. J. F. Daniell, that silicium exists in some of the varieties of cast iron: (*Journal of Science and Arts*, Vol. ii.), and an alloy containing it has been formed by M. M. Stromeyer and Berzelius, (Gilbert's *Annalen*, xxxviii.) by exposing a mixture of pure iron, silica, and charcoal, to an intense heat.

1320. The fossils consisting of silica, pure, or nearly so, are principally the following:

i. *Rock-crystal*, or *Quartz*, which may be considered as pure silica. It crystallizes in the form of a six-sided prism, ended by six-sided pyramids; some varieties are perfectly transparent and colourless; others white and more or less opaque. Its specific gravity is 2.6. It is so hard as to give sparks when struck with steel, and is nearly infusible. The primitive crystal, which is very rare, is an obtuse rhomboid, the angles of which are 94° 24′, and 85° 36′. The finest specimens are brought from Madagascar and the Alps. The perfectly transparent crystals found near Bristol, and in Cornwall, are sometimes called *Bristol* and *Cornish diamonds.* The fine crystals are cut into ornaments, and sometimes used as a substitute for glass in spectacles;

they are then termed *pebbles*, and do not so readily become scratched as glass.

Brown and yellow crystals of Quartz are found in great beauty in the mountain of Cairn Gorm in Scotland, and are much admired for seal stones, *&c.*: they are sometimes improperly termed topazes.

Purple quartz, or *amethyst*, is tinged with a little iron and manganese. *Rose quartz* derives its colour from manganese. *Prase*, or *green quartz*, contains actinolite; and *chrysoprase* is tinged of a delicate apple-green by oxide of nickel. *Avanturine* is a beautiful variety of quartz, of a rich brown colour, which, from a peculiarity of texture, appears filled with bright spangles; the finest specimens are from Spain; it is often imitated. Small crystals of quartz, tinged with iron, are found in Spain, and have been termed *hyacinths of Compostella.*

ii. *Flint*, *Chalcedony*, *Carnelian*, *Onyx*, *Sardonyx*, and *Bloodstone* or *Heliotrope*, and the numerous varieties of *Agates* are principally composed of quartz, with various tinging materials.

iii. *Opal* is among the most beautiful productions of the mineral world; it is a compound of about 90 silica and 10 water, and is distinguished by its very brilliant play of colours. The finest specimens come exclusively from Hungary. There is a variety of opal called *Hydrophane*, which is white and opaque till immersed in water; it then resembles the former.

Common opal is usually of a dirty white, and does not exhibit the colours of the noble opal; it contains silica and water, with a little oxide of iron, and is not of unfrequent occurrence. The substance called *menilite* from Menil Montant, near Paris, is nearly allied to common opal. It is found in irregular masses in a bed of clay.

iv. *Pitchstone,* so called from its resinous appearance, contains 73 *per cent.* of silica. *Obsidian,* a volcanic product, contains 78 *per cent.* of silica, and much resembles glass in appearance; and the different kinds of *pumice* are nearly of similar composition.

SECTION XXXVIII. *Alumium.*

1321. THE earth alumina constitutes some of the hardest gems, such as the sapphire and ruby; and combined with water, it gives a peculiar softness and plasticity to some earthy compounds, such as the different kinds of clay. It is analogically considered as a metallic oxide.

1322. There can I think be little doubt of the existence of silicium and alumium, as well as of calcium, and probably magnesium, in some of the varieties of cast-iron and steel. By fusing highly carburetted steel with alumina, a peculiar alloy results, which is white, granular, and brittle, and which yields on analysis 6.4 *per cent.* alumina. On fusing 67 parts of this alloy with 500 of steel, a compound is obtained, which possesses all the characters of the best Bombay wootz (761), and like it, when its surface is polished and washed over with dilute sulphuric acid, exhibits the striated appearance called *damask*, for which the celebrated sabres of Damascus are remarkable, and which renders it probable that they also are made of wootz. (*Quarterly Journal of Science and Arts*, ix.). Many of the varieties of cast-iron afford lime and silica when dissolved in acids, and it is highly probable that those substances, as well as the alumina in the wootz, exist combined with the iron in their deoxidized or metallic state.

1323. To obtain *pure alumina* we add carbonate of ammonia to a solution of alum, wash, and ignite the precipitate; it is a tasteless white substance, forming a cohesive mass with water, and retaining water even at a red heat. Its specific gravity is 2. It is soluble in soda and potassa, and forms compounds with baryta, strontia, lime, and silica. It is an essential ingredient in pottery and porcelain.

1324. One of its saline combinations is of important use in the arts, namely, *alum; a triple sulphate of alumina and potassa.* This salt is usually prepared by roasting and lixiviating certain clays containing pyrites; to the leys, a certain quantity of potassa is added, and the triple salt is obtained by crystallization*.

Alum has a sweetish astringent taste. It dissolves in 5 parts of water at 60°, and the solution reddens blues. It furnishes octoëdral crystals. When heated, it loses water of crystallization and a part of its acid, and becomes a white spongy mass. In its crystalline

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* Sulphate of alumina will not crystallize; but if a solution of sulphate of potassa be added to solution of sulphate of alumina, small octoëdral crystals of alum are precipitated.

form it consists, according to some recent experiments made by Mr. R. Phillips, of

Sulphate of alumina	123.00
Bi-sulphate of potassa ...	119.32
Water	187.00
	429.32

Mr. Phillips adopts the number 24 as the representative of alumina, and considers alum as a compound of 2 proportionals of sulphate of alumina, 1 of bi-sulphate of potassa, and 22 of water. These proportions, therefore, would be

Bi-sulphate of potassa		= 120
Sulphate of alumina,	61.5 × 2	= 123
Water	8.5 × 22	= 187
		430

1325. When alum is exposed to an intense heat, it loses water, and a portion of acid; but the whole of the acid cannot be expelled. It becomes light and spongy; and in this state is called in the *Pharmacopœia, Alumen ustum,* or *exsiccatum.* If alum contain excess of potassa it forms cubic crystals, and is known under the name of cubic alum. Some varieties of alum contain ammonia.

1326. When alum is ignited with charcoal, a spontaneously inflammable compound results, which has long been known under the name of *Homberg's pyrophorus.* The potassa appears to be decomposed in this process, along with the acid of the alum, and pyrophorus is probably a compound of sulphur, charcoal, and potassium, with alumina.

Pyrophorus is most successfully prepared by the following process. Mix equal parts of honey, or of brown sugar and powdered alum, in an iron ladle, melt the mixture over a fire, and keep it stirred till dry: reduce the dry mass to powder, and introduce it into a common phial coated with clay, and placed in a crucible of sand. Give the whole a red heat, and when a blue flame appears at the neck of the phial, allow it to burn about five minutes, then remove it from the fire; stop the phial, and allow it to cool, taking care that air cannot enter it.

1327. Alum is of extensive use in the arts, more especially in dyeing and calico-printing, in consequence of the attraction which alumina has for colouring matter.

1328. A *triple sulphate of alumina and soda* is described in the *Quarterly Journal of Science and Arts*, (viii. 386.) in the form of irregular efflorescent octoëdra: it appears to contain

2	proportionals sulphate of alumina	61.5 × 2 =	123.
1	———— bi-sulphate of soda	...... =	104.5
28	———— water	..........8.5 × 28 =	238.
			465.5

1329. The remaining salts of alumina, with the exception of the acetate, which remains to be described, are of little importance; what is known respecting them is fully detailed by Dr. Thomson.—*System*, Vol. ii. p. 510.

1330. Under the term *corundum* certain mineral substances have been included, composed of alumina, nearly pure.

i. *Perfect corundum* occurs crystallized in six-sided prisms, transparent and colourless. Its specific gravity is about 4. When blue, it constitutes the *sapphire;* when red, the *ruby;* when yellow, the *oriental topaz,* or *chrysolite.* These gems are principally found in alluvial deposits. They are mostly procured from Ceylon and Pegu; they have also been found in France and in Bohemia.

ii. *Imperfect corundum,* or *adamantine spar* and *emery,* are nearly analogous in composition to the former; they contain from 3 to 5 *per cent.* of silica and 1 to 2 of oxide of iron.

iii. *Spinelle,* or *balass ruby,* is found in octoëdral crystals, of a red colour. It is composed of 74.5 alumina, 15.5 silica, 3.25 magnesia, 1.5 oxide of iron, and traces of lime and oxide of chrome. The *ceylanite,* or *pleonaste,* is a variety of spinelle. A variety, containing oxide of zinc, is called *zinc spinelle,* or *automalite.*

iv. The mineral, called *Wavellite,* or *hydrargillite,* is a compound of alumina, phosphoric acid, and water. It is found in Devonshire, in small radiated nodules upon clay-slate. According to Berzelius, (*Annales de Chim. et Phys.,* Tom. xii.) 100 parts afford

Alumina	35.35
Phosphoric acid	33.40
Fluoric acid	2.06
Lime	0.50
Oxides of iron and manganese	1.25
Water	26.80
	99.36

v. The *occidental topaz,* found chiefly in Saxony, Siberia, Brazil, and Scotland, consists of alumina, silica, and fluoric acid. The *schorlous beryl* or *pycnite,* and the *pyrophysalite,* are nearly of the same composition.

vi. *Cryolite,* a rare substance hitherto only found in Greenland, consists of alumina, soda, and fluoric acid. It is white, amorphous, and translucent.

vii. A mineral, called *native alumina,* is found upon the Sussex coast, near Newhaven. It is white and friable, and occurs massive and incrusting. It contains alumina and sulphate of lime.

1331. A very numerous and important class of minerals consists of a combination of silica with alumina, in various proportions, and with the occasional addition of the fixed alcalis or alcaline earths, and a few of the other metallic oxides: the principal of these, which are not elsewhere mentioned, are the following:

i. *Zeolite.*—Of this mineral there are several varieties. The principal are the *radiated* or *mesotype ;* the *nacreous* or *stilbite ;* the *efflorescent* or *laumonite ;* and the *cubic* or *analcime.* These minerals fuse and intumesce before the blow-pipe, and mostly form gelatinous solutions in the acids. The following is Vauquelin's analysis of a radiated or acicular zeolite:

Silica	50.24
Alumina	29.30
Lime	9.46
Water	10.00

ii. *Apophyllite* and *Chabasite* are nearly of the same composition; except that the latter contains about 9 *per cent.* of potassa and soda.

iii. *Garnet* occurs massive, but generally crystallized in dodecaëdra. The *precious garnet* is red and transparent; the *common garnet*, red, brown, or green. According to Vauquelin, the precious garnet consists of

Silica	36
Alumina	20
Oxide of iron	41
Lime	3

The *cinnamon stone* of Ceylon is nearly of similar composition.

iv. *Melanite*, or *black garnet*, contains, upon the same authority,

Silica	35
Alumina	6
Lime	32
Oxides of iron and manganese	25

v. *Leucite*, or *white volcanic garnet*, contains, according to Klaproth,

Silica	54
Alumina	24
Potassa	21

vi. *Vesuvian*, or *idocrase*, is brown or yellow red, and is found crystallized in the masses of rock ejected by Vesuvius and Etna. It has also been found in the Alps and in Siberia. The Neapolitan lapidaries call it *chrysolite of Vesuvius.* In composition it differs little from melanite.

vii. *Staurotide,* or *grenatite,* crystallizes in four and six-sided prisms often crossing each other. It consists of

Silica	33
Alumina	44
Lime	3.8
Oxides of iron and manganese	14

viii. *Sodalite* and *natrolite* are minerals containing a considerable portion of soda. The former has been analyzed by Dr. Thomson. It has hitherto only been found in Greenland and on Vesuvius. Its colour is light green, and it occurs massive and crystallized in rhomboidal dodecaëdra. It consists of

38.42	silica
27.48	alumina
23.50	soda
2.70	lime
3.00	muriatic acid
1.00	oxide of iron
2.10	volatile matter

ix. *Prehnite* is of a greenish colour, and radiated fracture. It occurs massive and crystallized in prisms. A lamellar variety has been called *koupholite.* It is found near the Cape of Good Hope, and in France and Scotland.

x. *Spodumene,* or *triphane,* is a mineral already alluded to in the section on Lithium. It is nearly allied to feldspar, and consists of

65	silica
25	alumina
8	lithia
2	oxide of iron.
100	

xi. *Scapolite*, and *Elaolite*, or *Fettstein*, are minerals hitherto found only in Norway: they contain about 45 *per cent.* of silica, and 33 of alumina. The scapolite contains about 18 *per cent.* of lime; the *elaolite*, the same proportion of potassa and soda.

xii. *Nephritic stone*, or *jade*, which is found in the Alps, and in China and India, contains, according to Saussure,

53.7	silica
12.7	lime
7	oxide of iron and manganese
10.7	soda
8.5	potassa
7.4	water and loss.
100.0	

The Chinese cut this substance into figures, and it is sometimes used for the handles of cutting-instruments. In New Zealand and other islands of the Pacific Ocean it is used for cutting instruments, in consequence of its hardness and toughness. Hence it has been called *axe stone*.

xiii. *Schorl* and *Tourmalin* consist principally of silica, alumina, and oxide of iron. They occur in prismatic crystals of a black colour.

xiv. *Thallite, epidote*, or *pistacite*, is nearly allied in composition to schorl. It occurs in green prismatic crystals.

xv. *Axinite*, or *thumerstone*, is found crystallized in flat oblique rhombs, of a brown, bluish, or grey tint, and transparent. It consists, according to Vauquelin, of

Silica	44
Alumina	18
Lime	19
Oxide of iron	14
Oxide of manganese	4

xvi. *Cyanite* is of a blue and grey colour, translucent, and occurs massive and prismatic. It consists, according to Klaproth, of

Alumina	55.5
Silica	43.0
Oxide of iron	0.5

xvii. *Lepidolite* occurs massive, and of a purplish colour and lamellar texture. According to Klaproth, it contains

Silica	54.5
Alumina	38.25
Potassa	4.
Oxide of iron and manganese	0.75

xviii. *Actinolite* is of a green colour, and generally occurs in aggregated masses of prismatic crystals. It contains

Silica	50.
Lime	9.7
Magnesia	19.2
Alumina	0.7
Oxides of chrome and iron	8.

xix. *Tremolite* is nearly white, fibrous and semi-transparent. It contains

Silica	62
Lime	14
Magnesia	13
Oxide of iron	6

xx. *Asbestos* is a soft fibrous flexible mineral, of a white or greenish tint, composed of

Silica	60
Magnesia	30
Lime	6
Alumina	4

Amianthus, *mountain cork*, and *mountain wood*, are varieties of asbestos.

xxi. *Lapis lazuli* consists of

Silica	46
Carbonate of lime	28
Alumina	14
Sulphate of lime	6.5
Oxide of iron and water	5

The blue colour is probably derived from some principle which has hitherto escaped analysis. It is prepared for painters under the name of *ultra-marine*.

xxii. *Harmotome*, *Staurolite*, or *Cross-stone*, occurs in small quadrangular prisms terminated by four rhombic planes, crossing each other. It is also found in single crystals. It is found at Andreasberg, in the Hartz, and at Strontian, in Scotland. It consists, according to Klaproth, of

Silica	49
Alumina	16
Baryta	18
Water	15

xxiii. *Augite* is a mineral of a black or brownish green colour, found in volcanic products, and in some basalts. *Sahlite* and *coccolite* are varieties of augite. It is composed of

Silica	52
Lime	13
Oxide of iron and manganese	16
Magnesia	10
Alumina	9

xxiv. *Datholite* is a combination of

Silica	38
Lime	34
Boracic acid	22
Water	4

It has only been found in Norway.

1332. Under the term *Clay* is comprehended a variety of mixtures of silica and alumina, more or less pure, and characterized by a peculiar plasticity in their moist state. The following are the principal varieties. 1. *Porcelain Clay*, derived principally from the decomposition of feldspar, and containing silica and alumina, sometimes with traces of oxide of iron; it is very difficult of fusion. 2. *Marly Clay*, which, with silica and alumina, contains a portion of carbonate of lime; it is much used in making pale bricks, and as a manure, and when highly heated enters into fusion. 3. *Pipe Clay*, which is very plastic and tenacious, and requires a higher temperature than the preceding for fusion; when burned it is of a cream colour, and used for tobacco-pipes and white pottery. 4. *Potters' Clay*, is of a reddish or grey colour, and becomes red when heated; it fuses at a bright red heat: mixed with sand it is manufactured into red bricks and tiles, and is also used for coarse pottery.

1333. The better kind of *pottery*, called in this country *Staffordshire ware*, is made of an artificial mixture of alumina and silica; the former obtained in the form of a fine clay, from Devonshire chiefly; and the latter consisting of chert or flint, which is heated red-hot, quenched in water, and then reduced to powder. Each material, carefully powdered and sifted, is diffused through water, mixed by measure, and brought to a due consistency by evaporation: it is then highly plastic, and formed upon the potter's wheel and lathe into various circular vessels, or moulded into other forms, which, after having been dried in a warm room, are enclosed in baked clay cases resembling bandboxes, and called *seggars:* these are ranged in the kiln so as nearly to fill it, leaving only space enough for the fuel; here the ware is kept red-hot for a considerable time, and thus brought to the state of *biscuit.* This is afterwards *glazed*, which is done "by dipping the biscuit ware into a tub containing a mixture of about 60 parts of litharge, 10 of clay, and 20 of ground flint, diffused in water to a creamy consistence, and when taken out enough adheres to the piece to give an uniform glazing when again heated. The pieces are then again packed up in the seggars, with small bits of pottery interposed between each, and fixed in a kiln as before. The glazing mixture fuses at a very moderate heat, and gives an uniform glossy coating, which finishes the process when it is intended for common white ware."—*Aikin's Dictionary.* Art. Pottery.

1334. The patterns upon ordinary porcelain, which are chiefly in blue, in consequence of the facility of applying cobalt, are generally printed off upon paper, which is applied to the plate or other article while in the state of biscuit, and adheres permanently to the surface when heat is properly applied.

1335. The manufacture of *porcelain* is a most refined branch of art; the materials are selected with the greatest caution, it being necessary that the compound should remain perfectly white after exposure to heat: it is also required that it should endure a very high temperature without fusing, and at the same time acquire a semivitreous texture and a peculiar degree of translucency and toughness. These qualities are united in some of the oriental porcelain, or *China*, and in some of the old Dresden, but they are rarely found co-existent in that of modern European manufacture. Some of the French and English porcelain, especially that made at Sèvres and at Worcester, is extremely white and duly translucent, but it is more apt to crack by sudden changes of temperature; more brittle, and consequently requires to be formed into thicker and heavier vessels; and more fusible than the finest porcelains of Japan and China.

1336. The colours employed in painting porcelain are the same metallic oxides enumerated for colouring glass, and in all the more delicate patterns they are laid on with a camel-hair pencil, and generally previously mixed with a little oil of turpentine. Where several colours are used, they often require various temperatures for their perfection, in which case those that bear the highest heat are first applied, and subsequently those which are brought out at lower temperatures. This art of painting on porcelain or in enamel is of the most delicate description; much experience and skill are required in it, and with every care there are frequent failures; hence it is attended with considerable expense. The gilding of porcelain is generally performed by applying finely-divided gold mixed up with gum-water and borax; upon the application of heat the gum burns off, and the borax vitrifying upon the surface causes the gold firmly to adhere; it is afterwards burnished.

1337. In the manufacture of various kinds of pottery employed in the chemical laboratory, and especially in regard to *crucibles*, many difficulties occur; and many requisites are necessary which cannot be united in the same vessel: to the late Mr. Wedgwood we are indebted for vast improvements in this as well as in other branches of the art.

Crucibles composed of one part of pure clay mixed with about three parts of coarse and pure sand, slowly dried and annealed, resist a very high temperature without fusion, and generally retain metallic substances; but where the metals are suffered to oxidize, there are few which do not act upon any earthen vessel, and some cause its rapid fusion, as the oxides of lead, bismuth, *&c.* Where saline fluxes are used, the best crucibles will always suffer, but platinum may often be employed in these cases, and the chemist is thus enabled to combat many difficulties which were nearly insurmountable before this metal was thus applied.

Whenever siliceous and aluminous earths are blended, as in the mixture of clay and sand, the compound softens, and the vessel loses its shape when exposed to a long-continued white heat, and this is the case with the *Hessian* crucibles: consequently, the most refractory of all vessels are those made entirely of clay, coarsely-powdered burned clay being used as a substitute for the sand. Such a compound resists the action of saline fluxes longer than any other, and is therefore used for the pots in glass furnaces. A Hessian crucible lined with purer clay is rendered much more retentive; and a thin china cup or other dense porcelain resists the action of saline matters in fusion for a considerable time.

Plumbago is a very good material for crucibles, and applicable to many purposes: when mixed with clay it forms an infusible compound and is protected from the action of the air at high temperatures; it is well calculated for small table furnaces. Wrought-iron crucibles are used for the fusion of several metallic substances which melt at a bright red heat.

1338. Under the term *Lutes* a variety of compounds are used by the practical chemist for the purpose of securing the junctures of vessels or protecting them from the action of heat. Slips of wetted bladder, linseed meal made into a paste with gum-water, white of egg and quicklime, glaziers' putty which consists of chalk and linseed oil; and *fat lute* composed of pipe clay and drying oil well beaten to a stiff mass, are very useful lutes for retaining fumes and vapours and joining vessels to each other, but earthy compounds are required to withstand the action of a high temperature.

Windsor loam, or an artificial mixture of clay and sand well beaten into a stiff paste, and then thinned with water and applied by a brush in successive layers, to retorts, tubes, gun-barrels, *&c.*, enables them to bear a very high temperature; if a thick coating is required, great care should be taken that the cracks are filled up as it dries, and often a little tow mixed up with the lute renders it more permanent and applicable. If the lute is intended to vitrify, as, for instance, to prevent the porosity of earthenware at high temperatures, a portion of borax or of red lead may be mixed up with it.

1339. *Mortar*, or the cement used in building, is a compound of several earthy substances, one of which is always lime; for much valuable information relating to this important subject we are indebted to the late Mr. Smeaton, (*History of the Eddystone Lighthouse*,) and an excellent summary of the principal facts connected with it will be found in AIKIN'S *Dictionary*, (Art. CEMENTS.)

The ordinary mode of making mortar consists in mixing a quantity of common sand with slacked lime, without any careful attention to the quantity or purity of the materials; but it has been shown by Mr. Smeaton, that the presence of unburnt clay prevents the induration of the mortar, and the sand used in London always contains it; the lime too is often imperfectly burned and seldom duly selected; that which contains a portion of alumina and oxide of iron being preferable to the purer varieties; hence the advantage of *Dorking* lime, or *meagre lime*, as it is usually called. The sand should be sharp and large grained, and perfectly free from salt, which always prevents the mixture from becoming hard. The addition of calcined ferruginous clay, or calcined basalt, or black oxide of iron, gives mortar the property of becoming hard under water.

The mutual action which the substances constituting the different kinds of mortar undergo, has hitherto been but imperfectly examined by the chemist; to M. Vicat we are indebted for a curious and important series of investigations upon this subject, and his work may be consulted with much advantage, by those who are concerned in investigations of this nature.—*Recherches Expérimentales sur les Chaux de Construction, les Bétons, et les Mortiers ordinaires.* Paris, 1818.

SECTION XXXIX. *Zirconium.*

1340. THE earth *zircon*, or the *oxide of zirconium*, is a white insipid substance; specific gravity 4.3; it is found in the zircon or *jargon* of Ceylon. It is characterized by insolubility in pure alcalis, but is soluble in alcaline carbonates. Its combinations with the acids are of difficult solubility or insoluble, and have been very little inquired into.

i. The *zircon*, or *jargon*, is a mineral, usually of a grey yellowish, or reddish-brown colour, crystallized in octoëdrons and four-sided prisms, and generally semi-transparent.

ii. *Zirconia* is contained in the *hyacinth*, which is also found in Ceylon, and in various parts of Europe. Its usual colour is red or reddish, and its crystals small flattened octoëdra, or four-sided prisms. These minerals contain about 70 *per cent.* of zirconia each, the remainder being silica, with a trace of oxide of iron.—KLAPROTH's *Beitrage*, Vol. i. pp. 222 and 231.

1341. Zirconia is obtained by the following process:

Reduce the stone to a fine powder, having previously heated it to redness, and quenched it in water. Mix the powder with nine times its weight of pure potassa, and gradually project it into a red-hot silver crucible, and keep it in perfect fusion for two hours. When the crucible has cooled, reduce the mass to a fine powder, and boil it in distilled water. Boil the undissolved residue in muriatic acid; filter, and evaporate to dryness; re-dissolve the dry mass in distilled water, and precipitate by carbonate of soda. The carbonate of zirconia which falls may be decomposed by heat.

The following method of obtaining pure zirconia is recommended by M. M. Dubois and Silveira.—*Annales de Chim. et Phys.*, xiv. 110:

Powder the zircons very fine, mix them with two parts of pure potassa, and heat them red-hot in a silver crucible for an hour. Treat the substance obtained with distilled water, pour it on a filter, and wash the insoluble part well; it will be a compound of zirconia, silica, potassa, and oxide of iron. Dissolve it in muriatic acid, and evaporate to dryness, to separate the silica. Re-dissolve the muriates of zirconia and iron in water; and to separate the zirconia which adheres to the silica, wash it with weak muriatic acid, and add it to the solution. Filter the fluid, and precipitate the zirconia and iron by pure ammonia; wash the precipitates well, and then treat the hydrates with oxalic acid, boiling them well together, that the acid may act on the iron, retaining it in solution whilst an insoluble oxalate of zirconia is formed. It is then to be filtered, and the oxalate washed, until no iron can be detected in the water that passes. The earthy oxalate is, when dry, of an opaline colour; after being well washed, it is to be decomposed by heat in a platinum crucible. Thus obtained, the zirconia is perfectly pure, but is not affected by acids. It must be re-acted on by potassa as before, and then washed until the alcali is removed. Afterwards dissolve it in muriatic acid, and precipitate by ammonia. The hydrate thrown down, when well washed, is perfectly pure, and easily soluble in acids.

1342. The composition of zirconia has been estimated by Sir H. Davy (*Elements of Chemical Phil.* p. 361.) at

35.	zirconium
7.5	oxygen.
42.5	

SECTION XL. *Glucinum.*

1343. THE earth *glucina* was discovered by Vauquelin in the beryl: it also exists in the emerald of Peru. It is white and insipid; its specific gravity = 2.97. It dissolves in caustic potassa and soda, and thus resembles alumina, but differs from yttria. Again it differs from alumina, but resembles yttria, in being soluble in carbonate of ammonia; it is much more soluble in this solution than yttria. With the acids it forms saline compounds of a sweetish astringent taste.

i. The *beryl* is found in primitive rocks in many parts of the world, but especially fine in Siberia. It is usually transparent, and pale green or blue. It crystallizes in six-sided prisms.

ii. The *emerald* is principally found in Peru, crystallized in regular six-sided prisms, the edges or angles of which are sometimes replaced by facets. Its colour is green, and it is either transparent or translucent. The following are their component parts.—VAUQUELIN, *Journal des Mines*, No. xxxvi, and No. xliii :

	Beryl.		Emerald.
Silica.	68	. . . . . .	64.5
Alumina	15	. . . . . .	16
Glucina	14	. . . . . .	13
Oxide of chrome	—	. . . . . .	3
Oxide of iron . . .	1	. . . . . .	—
Lime	2	. . . . . .	1.5
Water	—	. . . . . .	2
	100		100

iii. Glucina is also found in the *euclase*, a very scarce Peruvian mineral, composed, according to Berzelius, of

Silica	44.33
Alumina	31.83
Glucina	23.84
	100.00

1344. To obtain glucina from either of these minerals, proceed as follows:—Reduce it to a fine powder, and fuse it with thrice its weight of potassa; dissolve in a dilute muriatic acid; evaporate to dryness; re-dissolve in water, and precipitate by carbonate of potassa. Dissolve this precipitate in sulphuric acid and add a little sulphate of potassa, and on evaporation crystals of alum will be obtained. These being separated, add excess of carbonate of ammonia to the residuary liquor, which will retain glucina in solution, but the alumina will be precipitated; filter, and evaporate to dryness, and apply a red heat; glucina remains.

1345. From the experiments of Davy, this earth may be regarded as consisting of

20	glucinum
7.5	oxygen
27.5	glucina.

SECTION XLI. *Yttrium.*

1346. IN 1794 Professor Gadolin discovered a new earth in a mineral from the quarry of Ytterby in Sweden, to which Ekeberg, in 1797, gave the name of *Yttria*. The mineral has since been termed *Gadolinite*. Oxide of yttrium, or yttria, may be obtained by the following process: Pulverise the mineral and boil in repeated portions of nitro-muriatic acid; evaporate nearly to dryness, dilute with water, and filter; evaporate to dryness, ignite the residue for some hours in a close vessel, re-dissolve and filter. To this solution add ammonia, which throws down yttria and oxide of cerium; heat the precipitate red-hot, dissolve it in nitric acid, and evaporate to dryness; dilute with 150 parts of water, and put crystals of sulphate of potassa into the liquid. The crystals gradually dissolve, and, after some hours, a white precipitate appears of oxide of cerium, the whole of which must be separated by a repetition of this process. The liquor is then to be filtered, and the addition of pure ammonia forms a precipitate of yttria, which is to be washed and heated red-hot.—BERZELIUS in THOMSON'S *Chemistry*. Vol. i. p. 357.

1347. Yttria is insipid, white, and without action on vegetable colours. It is insoluble in water, but very retentive of it. Insoluble in pure alcalis, but readily soluble in carbonated alcalis. It forms salts which have a sweetish austere taste, and which have been little examined. From indirect experiments it probably contains 25 *per cent.* oxygen; hence it may be regarded as consisting of

30	yttrium
7.5	oxygen
37.5	yttria.

SECTION XLII. *Thorinum.*

1348. IN examining some varieties of gadolinite and certain ores of cerium, Berzelius obtained a new metallic oxide, the base of which he has called *thorinum.* The accounts hitherto published of the mode of procuring this substance, are by no means sufficiently clear or circumstantial to enable the student to repeat them, but the process of analysis of the minerals containing it will be found in the section on the compounds of thorinum in the ensuing chapter.

1349. Thorina differs from alumina in being insoluble in solution of potassa; from yttria, by its astringent taste without sweetness, and by its neutral solutions affording a precipitate when boiled. From zirconia it differs in the following properties: 1. After being heated to redness it is still soluble in acids. 2. Sulphate of potassa occasions no precipitate in its solutions. 3. It is precipitated by oxalate of ammonia. 4. Sulphate of thorina crystallizes, while sulphate of zirconia does not.—THOMSON, Vol. i. p. 567.

CHAPTER VI.

OF THE ASSAY AND ANALYSIS OF METALLIFEROUS COMPOUNDS.

1350. The chemical history of the metals, given in the preceding chapter of this volume, includes some account of the method of analyzing certain of their compounds, but upon this subject many details have necessarily been omitted in the different sections treating of the metals individually, in consequence of the numerous digressions that such discussion would have introduced; in the present chapter, therefore, it is proposed to describe such analytical processes as have not previously been adverted to, and are of frequent occurrence in the chemical laboratory; and likewise to point out the means of detecting impurities and adulterations in the various chemical products used in medicine and in the arts.

1351. It is scarcely necessary to observe that in all analytical operations distilled water is to be employed, and that the purity of the tests and re-agents must be previously ascertained: it is also convenient that they should be of some known degree of strength or concentration.

1352. Among the most important apparatus of the chemical analyst, is a good balance; he will generally find it convenient to employ two; one, extremely delicate and capable of weighing from one-hundredth of a grain up to fifty grains; the other, less sensible, but turning with one-tenth of a grain, when loaded with about an ounce in each scale. Larger balances are often requisite for weighing from one ounce to five or six pounds.

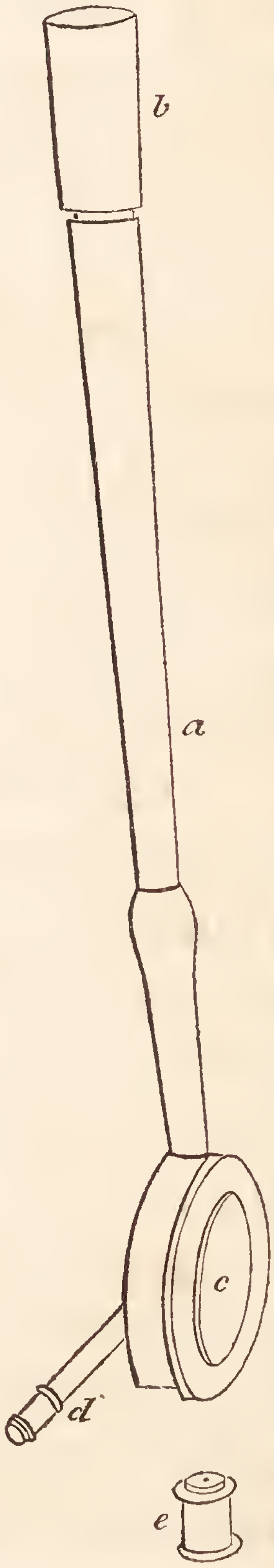
1353. For the disintegration of very hard substances, mortars of hard steel, agate, or porphyry, are generally used, and the substance should be accurately weighed before and after pulverization, in order to ascertain whether it has suffered any increase from the abrasion of the mortar. The aggregation of many very hard stony substances may be diminished by heating them red-hot and quenching in water; but care should be taken to ascertain the nature and quantity of any loss which they may sustain in this operation.

1354. The proportion of any substance for an analysis varies, in ordinary cases, from twenty to one hundred grains; fifty grains is, generally speaking, a convenient quantity, and where there is no scarcity of the material, it is often advantageous to operate upon two or three portions at once, using each portion for ascertaining a distinct component part.

1355. The crucibles employed in these analytical operations are either metallic, earthenware, or porcelain. Of the former, platinum, silver, and iron are chiefly useful; platinum resists the action of the greater number of acids, but it is acted upon by alcaline substances; pure silver is chiefly useful for alcaline-fusions, but as it melts at a red heat, some care is requisite in its employment; for metallic substances, Hessian and Wedgwood crucibles are required; the former, when well made, resist a very high heat without fusion, and bear sudden changes of temperature; the latter are apt to crack, and should therefore be carefully heated, or placed in a Hessian crucible. It is often necessary to line a crucible with charcoal, which is most conveniently effected by mixing finely-powdered charcoal with a very little linseed-meal, and beating it into a stiff paste with a small addition of water; the crucible is then dipped into water, and its interior lined to the requisite thickness; on applying heat, the linseed-meal burns, but the coating is not injured.

1356. In the examination of mineral substances, the blowpipe is a most useful and necessary auxiliary to our other operations; it affords a simple and convenient means of heating to a very high degree, and almost instantaneously, any substance sufficiently small to be enveloped in its flame; and the experienced eye is thus frequently enabled to anticipate, with much precision, the nature of the substance submitted to experiment.

There are numerous forms of the blow-pipe, among which, that represented in the annexed cut is perhaps the most convenient. It consists of a brass tube *a*, with an ivory mouthpiece *b*; the other end of the tube terminates in a circular box, from which issues the small tube *d*, moveable in any direction round the centre *c*, by which any degree of obliquity may conveniently be given to the flame; *e* is a brass jet which fits upon the tube *d*.



1357. The following observations respecting the use of the blowpipe, and its action upon several substances, are extracted from Mr. Children's *Essay on Chemical Analysis:* a work from which the student may derive much valuable information.

A continued stream of air is absolutely essential, to produce which, without fatigue to the lungs, an equable and uninterrupted inspiration must be maintained by inhaling air through the nostrils, whilst that in the mouth is forced through the tube by the compression of the cheeks. A little practice will make this operation easy, but at first considerable lassitude is generally experienced in the buccinator muscles. After habit has rendered the operation familiar, a current may be kept up for ten or fifteen minutes, without inconvenience. A large wax candle supplies the best flame, which being urged by the blast, exhibits two distinct figures; the internal flame is conical, blue, and well defined, at the apex of which the most violent degree of heat is excited; the external is red, vague, and undetermined, and of very inferior temperature to the former.

The substance to be submitted to the action of the blow-pipe, which should not be larger than a small pepper-corn, must be supported either on charcoal, or a slip of platina or silver foil, or be held in a pair of platina pincers. In the first case it may be placed in a cavity in the charcoal, and another piece laid over it to prevent its being carried off by the blast. The metallic supports are used when the subject of the experiment is intended to be exposed to the action of heat only, and might be altered by contact with the charcoal. If a very intense heat be required the foil may be laid on charcoal. Salts and volatile substances, are to be heated in glass tubes, closed at one end, and enlarged according to circumstances, so as to form small matrasses.

The exterior flame should first be directed on the substance, and when its action is known, then the interior blue flame. Notice should be taken, whether the matter decrepitates, splits, swells up, liquefies, boils, vegetates, changes colour, smokes, is inflamed, becomes obedient to the magnet, *&c.* *; when the action of heat alone

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* M. Haüy has proposed the following ingenious method of rendering very weak magnetic attractions perceptible:

If we conceive the needle to be removed a little from the plane of its magnetic meridian, its directing force will immediately tend to restore it, and with a power proportionate to the size of the angle which the needle makes with the magnetic meridian. Before any substance can act on the needle, it will have to overcome the directing force, as well as the friction at the point of suspension; obstacles which may prevent the effect of very slight attractions from being perceived. To diminish the force opposed to the action of the needle, M. Haüy places a magnetic bar at a certain distance from it, on the same level and in the direction of its axis, but with its poles situated contrary to those of the needle. If we suppose the magnetic bar to be placed to the south of the needle, the south pole of the magnet and the needle will be opposed to each other, and if the magnet be made to approach the needle, the latter will move on its centre towards one side or the other, till an equilibrium is produced between the mutual action of the magnet and needle, and that of the needle and the earth. Coulomb has shewn that in proportion as the needle deviates from its natural position, the increments of power necessary to produce equal effects, are in a decreasing ratio; so that when it has moved through nearly a quarter of a circle, a very small attractive power will be sufficient to influence it. When it is in this position, that is, nearly at right angles with the magnetic meridian, the needle is has been ascertained, it will be necessary to examine what further change takes place, by fusing it with various fluxes, and also whether it be capable of reduction to the metallic state.

The three most useful fluxes, are the triple phosphate of soda and ammonia, subcarbonate of soda and borax. These are to be kept ready pulverised, and when used, a sufficient quantity may be taken up by the moistened point of a knife; the moisture causes the particles to cohere and prevents their being blown away, when placed on the charcoal. The flux must be melted into a clear bead, and the substance then placed on it, and submitted, first to the action of the exterior, and then to that of the interior, flame. The appearances which ensue must be observed; as,

1st. If the substance be dissolved, and whether with or without effervescence:

2nd. The transparency, and colour of the glass whilst cooling;

3rd. The same circumstances, when cold;

4th. The nature of the glass formed by the exterior flame;

5th. Also, by the interior flame.

6th. The particular appearances with each of the fluxes.

Subcarbonate of soda does not form a bead on char-

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in its most sensible state; and is affected if any substance containing the most minute portion of iron be presented to it.

Haüy has by this method detected iron in several minerals where its presence was not suspected, or where it was supposed to exist in a state not liable to be affected by the magnet.—*Annals of Philosophy*, Vol. xii. p. 117.

coal, but with a certain degree of heat is absorbed; it must therefore be added in very small quantities, and a gentle heat used at first, which will promote combination without the absorption of the alkali. Some minerals combine readily with very small portions of soda, but difficultly if more be added, and are absolutely infusible with it in great excess; and when the substance has no affinity for this flux, it is absorbed by the charcoal, and no combination ensues.

When the mineral contains sulphur or sulphuric acid, the glass acquires a deep yellow colour, which by the light of a lamp appears red, as if produced by copper.

If the glass bead become opaque as it cools, so as to render the colour indistinct, it should be broken and a part of it mixed with more of the flux, till the colour becomes purer, and distinct. To make the colour more perceptible, the bead may be flattened whilst soft, or drawn out to a thread.

If it be wished to *oxidate* a metallic substance, combined with either of the fluxes, the glass is first heated intensely, and when fused, gradually withdrawn from the point of the blue flame, and the operation repeated, as often as necessary, using a jet of large aperture. The addition of a little nitre also assists the oxidation. For the *reduction* of metallic oxides, the glass bead is to be kept in fusion on charcoal, as long as it remains on the surface and is not absorbed, that the metallic particles may collect into a globule. It is then to be fused with an additional quantity of soda, which will be absorbed by the charcoal, and the spot where the absorption has taken place, strongly ignited by a tube with a small aperture. By continuing the ignition, the portion of metal which was not previously reduced, will now be brought to the metallic state, and the process may be assisted, by placing the bead in a smoky flame, so as to cover it with a soot that is not easily blown off.

The beads which contain metals frequently have a metallic splendour, which is most easily produced by a gentle, fluttering, smoky flame, when the more intense heat has ceased. With a moderate heat the metallic surface remains; and by a little practice it may generally be known whether the substance under examination contains a metal or not. But the glass of borax alone sometimes assumes externally a metallic appearance.

When the charcoal is cold, that part impregnated with the fused mass should be taken out with a knife, and ground with distilled water in an agate mortar. The soda will be dissolved; the charcoal will float, and may be poured off; and the metallic particles will remain in the water, and may be examined.

In this manner most of the metals may be reduced.

Action of the Blowpipe on the Earths and Metallic Oxides.

Baryta (627), when containing water, melts and spreads on the charcoal. Combined with sulphuric acid, it is converted, in the *interior* flame, into a sulphuret, and is absorbed by the charcoal, with effervescence, which continues as long as it is exposed to the action of the instrument.

Strontia (652), if combined with carbonic acid, when held in small thin plates with platinum forceps in the *interior* flame, has its carbonic acid driven off, and on the side of the plate furthest from the lamp, a red flame is seen, sometimes edged with green, and scarcely perceptible but by the flame of a lamp. Sulphate of strontia is reduced in the *interior* flame to a sulphuret; dissolve this in a drop of hydrochloric acid, add a drop of alcohol, and dip a thin slip of deal in the solution; it will burn with a fine red flame.

Lime (618).—The carbonate is easily rendered caustic by heat: it then evolves heat on being moistened, turns paper stained with turmeric brown, and is infusible before the blowpipe. The sulphate is easily reduced to a sulphuret, and possesses, besides, the property of combining with fluor spar at a moderate heat, forming a clear glass. The fluor should be rather in excess.

Magnesia (671) produces, like strontia, an intense brightness in the flame of the blowpipe. A drop of a solution of cobalt being added to it, and then dried and strongly ignited, a faint flesh red colour, scarcely visible by the light of a lamp, is produced.

Magnesia may in this manner be detected in compound bodies, if they do not contain much metallic matter, or a quantity of alumina, exceeding that of the magnesia. Some inference, as to the proportion of the magnesia, may be drawn from the intensity of the colour produced.

All these alkaline earths, when pure, are readily fusible with the fluxes, into a clear, colourless glass, without effervescence; but on adding a further quantity of the earth, the glass becomes opaque.

Alumina (1323) combines more slowly with the fluxes than the preceding earths, and forms a clear glass, which does not become opaque. But the most striking character of alumina is the bright blue colour it acquires from the addition of a drop of nitrate of cobalt, after having been dried and ignited for some time. It may thus be detected in compound minerals where the metallic substances are not in great proportion, nor the quantity of magnesia large.

The following, according to Berzelius, is a ready method of discovering *lithia* (609) in any mineral supposed to contain it; it is founded on the facility with which that alkali attacks platinum.

Take a morsel of the mineral, about the size of a pin's head, or a small quantity of it reduced to fine powder, and heat it with an excess of soda, on a slip of platinum foil before the blowpipe, and keep it red hot for about two minutes. The stone will be decomposed, the soda will expel the lithia from its combination, and the excess of alkali, becoming fluid at this temperature, will spread over the surface of the foil, and envelope the decomposed mass. The platinum round the fused alkaline mass assumes a dark colour, deep and extensive in proportion to the quantity of lithia in the mineral. The platinum beneath the alkali is not oxidated, but only in those parts where it is in contact both with the air and the lithia. Potassa destroys the action of platinum on the lithia, if it be not in considerable quantity. The metal recovers its brilliancy after being well washed with water and heated to redness.—*Annales de Chimie*, Vol. x. p. 104, note.

Metallic Oxides and Acids.

Arsenic (1013) flies off accompanied by its characteristic smell, resembling garlic. When large pieces of white arsenic are heated on ignited charcoal, no smell is perceived. To produce this effect, the white oxide must be reduced by being mixed with powdered charcoal. If arsenic be suspected in a solution, it may be discovered by dipping into it a piece of pure and well-burnt charcoal, which is afterwards to be dried and ignited.

Chromium.—Its green oxide (1080) exhibits the following properties: it is fusible with microcosmic salt (phosphate of soda and ammonia) in the interior flame, into a glass which at the instant of its removal from the flame is of a violet hue, approaching more or less to dark blue or red, according to the proportion of the chromium. After cooling, the glass is bluish green, but less blue than copper glass. In the exterior flame the colour becomes brighter, and less blue than the former. With borax it forms a bright yellowish or yellow red glass in the exterior flame; and in the interior flame this becomes darker and greener, or bluish green.

Molybdic acid (1070) melts by itself upon the charcoal with ebullition, and is absorbed. In a platinum spoon it emits white fumes, and is reduced in the interior flame to molybdous acid, which is blue, but in the exterior flame it is again oxidated and becomes white. With microcosmic salt, in the exterior flame, a small proportion of the acid gives a green glass, which by gradual additions of the acid passes through yellow green to reddish, brownish, and hyacinth brown, with a slight tinge of green. In the interior flame the colour passes from yellow-green, through yellow-brown, and brown-red, to black; and if the proportion of acid be large, it acquires a metallic lustre, like the sulphuret, which sometimes remains after the glass has cooled. Molybdic acid is but sparingly dissolved by borax. In the exterior flame the glass acquires a grey-yellow colour. In the interior flame black particles are precipitated from the clear glass, leaving it almost colourless when the quantity of molybdenum is small, and blackish when the proportion is large. If to a glass formed of this acid and microcosmic salt a little borax be added, and the mixture fused in the exterior flame, the colour becomes instantly reddish-brown; in the interior flame the black particles are also separated, but in smaller quantity. By long-continued heat the colour of the glass is diminished, and it appears yellower by the light of a lamp than by day-light. This acid is not reduced by soda in the interior flame.

Tungstic Acid (1094, p. 226.) becomes upon charcoal at first brownish yellow, is then reduced to a brown oxide, and lastly, becomes black without melting or smoking. With microcosmic salt it forms in the interior flame a pure blue glass, without any violet tinge; in the exterior flame this colour disappears, and appears again in the interior. With borax, in the internal flame, and in small proportion, it forms a colourless glass, which by increasing the proportion of acid, becomes dirty grey, and then reddish. By long exposure to the external flame it is rendered transparent, but as it cools it becomes muddy, whitish, and changeable into red when seen by day-light. It is not reduced.

Oxide of Columbium (1092, p. 230.) undergoes no change by itself, but is readily fused with microcosmic salt and with borax, into a clear colourless glass, from which the oxide may be precipitated by heating and cooling it alternately. The glass then becomes opaque, and the oxide is not reduced.

Oxide of Titanium (992) becomes yellowish when ignited in a spoon, and upon charcoal dark brown. With microcosmic salt it gives in the interior flame a fine violet-coloured glass, more tending to blue than that from manganese. In the exterior flame this colour disappears. With borax it gives a dirty hyacinth colour.

Oxide of Cerium (998) becomes red brown when ignited. When the proportion is small it forms with the fluxes a clear, colourless glass, which by increasing the proportion of oxide becomes yellowish-green while hot. With microcosmic salt, if heated a long time in the internal flame, it gives a clear colourless glass.

With borax, under similar circumstances, it gives a faint yellow-green glass while warm, but is colourless when cold. Exposed again for some time to the external flame, it becomes reddish yellow, which colour it partly retains when cold. If two transparent beads, one of the compound with microcosmic salt, the other with borax, be fused together, the triple compound becomes opaque and white. The oxide is volatile.—See *Thomson's Chemistry,* Vol. i. p. 408, *5th edition.*

Oxide of Uranium (983).—The yellow oxide by ignition becomes green or greenish brown. With microcosmic salt in the interior flame it forms a clear yellow glass, the colour of which becomes more intense when cold. If long exposed to the exterior flame, and frequently cooled, it gives a pale yellowish, red-brown glass, which becomes greenish as it cools. With borax in the interior flame, a clear, colourless, or faintly green glass is formed, containing black particles, which appear to be the metal in its lowest state of oxidation. In the exterior flame this black matter is dissolved if the quantity be not too great, and the glass becomes bright yellowish-green, and after further oxidation yellowish-brown. If brought again into the interior flame, the colour gradually changes to green, and the black matter is again precipitated, but no further reduction takes place.

Oxide of Manganese (703) gives with microcosmic salt, in the exterior flame, a fine amethyst colour, which disappears in the interior flame. With borax it gives a yellowish hyacinth red glass. When the manganese, from its combination with iron, or any other cause, does not produce a sufficiently intense colour in the glass, a little nitre may be added to it while in a state of fusion, and the glass then becomes dark violet while hot, and reddish violet when cool. It is not reduced.

Oxide of Tellurium (1002), when gently heated, becomes first yellow, then light red and afterwards black. It melts and is absorbed by the charcoal, and is reduced with a slight detonation, a greenish flame and a smell of horse-radish. Microcosmic salt dissolves it without being coloured.

Oxide of Antimony (907) is partly reduced in the exterior flame, and spreads a white smoke on the charcoal. In the interior flame it is readily reduced, either alone or with the addition of soda. With microcosmic salt and with borax it forms a hyacinth coloured glass. Metallic antimony, when ignited on charcoal, becomes covered with radiating acicular crystals of white oxide.

Sulphuret of antimony melts on charcoal, and is absorbed.

Oxide of Bismuth (939) melts readily in a spoon to a brown glass, which becomes brighter as it cools. With microcosmic salt it forms a grey yellow glass, which loses its transparency, and becomes pale when cool. Add a further proportion of oxide, and it becomes opaque.

With borax it forms a grey glass, which decrepitates in the interior flame, and the metal is reduced and volatilized. It is readily reduced by itself on charcoal.

Oxide of Zinc (766) becomes yellow when heated, but whitens as it cools. A small proportion forms with microcosmic salt, and with borax a clear glass, which becomes opaque on increasing the quantity of oxide. A drop of nitrate of cobalt being added to the oxide and dried and ignited, it becomes green. With soda in the interior flame it is reduced, and burns with its characteristic flame, depositing its oxide upon the charcoal. By this process zinc may be easily detected even in the automalite. Mixed with oxide of copper, and reduced, the zinc will be fixed and brass obtained. But one of the most unequivocal characters of the oxide of zinc is, to dissolve it in vinegar, evaporate the solution to dryness, and expose it to the flame of a lamp, when it will burn with its peculiar flame.

Oxide of Cadmium (819) is orange yellow, not volatile, and easily reduced; it gives no colour to borax.—*Annales de Chimie et Phys.*, Tom. viii., p. 100.

Oxide of Iron (722) produces with microcosmic salt, or borax in the exterior flame, when cold, a yellowish glass, which is blood-red while hot. The protoxide forms with these fluxes a green glass, which by increasing the proportion of the metal passes through bottle-green to black, and is opaque. The glass from the peroxide becomes green in the interior flame, and is reduced to protoxide, and becomes attractable by the magnet. When placed on the wick of a candle, it burns with the crackling noise peculiar to iron.

Oxide of Cobalt (958) becomes black in the exterior, and grey in the interior flame; a small proportion forms with microcosmic salt and with borax a blue glass, that with borax being the deepest. By transmitted light the glass is reddish. By farther additions of the oxides, it passes through dark blue to black. The metal may be precipitated from the dark blue glass by inserting a steel wire into the mass while in fusion. It is malleable if the oxide has been free from arsenic, and may be collected by the magnet, and is distinguished from iron by the absence of any crackling sound when placed on the wick of a candle.

Oxide of Nickel (1096) becomes black at the extremity of the exterior flame, and in the interior greenish grey. It is dissolved readily, and in large quantity, by microcosmic salt. The glass while hot is a dirty dark red, which becomes paler and yellowish as it cools. After the glass has cooled, it requires a large addition of the oxide to produce a distinct change of colour. It is nearly the same in the exterior and interior flame, being slightly reddish in the latter. Nitre added to the bead makes it froth, and it becomes red brown at first and afterwards paler. It is easily fusible with borax, and the colour resembles the preceding. When this glass is long exposed to a high degree of heat in the interior flame, it passes from reddish to blackish and opaque, then blackish grey and transparent; then paler reddish grey, and clearer; and lastly, transparent, and the metal is precipitated in small white metallic globules.

The red colour seems here to be produced by the entire fusion or solution of the oxide, the black by incipient reduction, and the grey by the minute metallic particles before they combine and form small globules. When a little soda is added to the glass formed with borax, the reduction is more easily effected, and the metal collects itself into one single globule. When this oxide contains iron, the glass retains its own colour while hot, but assumes that of the iron as it cools.

Oxide of Tin (790), in form of hydrate, and in its highest degree of purity, becomes yellow when heated, then red, and when approaching to ignition black. If iron or lead be mixed with it, the colour is dark brown when heated. These colours become yellowish as the substance cools. Upon charcoal in the interior flame, it becomes and continues white; and if originally white, and free from water, it undergoes no change of colour by heating. It is very easily reduced without addition, but the reduction is promoted by adding a drop of solution of soda or potassa.

Oxide of Lead (872) melts, and is very quickly reduced, either without any addition, or when fused with microcosmic salt or borax. The glass not reduced is black.

Oxide of Copper (826) is not altered by the exterior flame, but becomes protoxide in the interior. With both microcosmic salt and borax it forms a yellow-green glass while hot, but which becomes blue-green as it cools. When strongly heated in the interior flame, it loses its colour, and the metal is reduced. If the quantity of oxide be so small that the colour be not perceptible, its presence may be detected by the addition of a little tin, which occasions a reduction of the oxide to protoxide, and produces an opaque red glass. If the oxide has been fused with borax, this colour is longer preserved; but if with microcosmic salt, it soon disappears by a continuance of heat. The copper may also be precipitated upon iron, but the glass must be first saturated with iron. Alkalies or lime promote this precipitation. If the glass containing copper be exposed to a smoky flame, the copper is superficially reduced, and the glass covered while hot with an iridescent pellicle, which is not always permanent after cooling. It is very easily reduced by soda. Salts of copper, when heated before the blowpipe, give a fine green flame.

Oxide of Mercury, (1133) before the blowpipe, becomes black and is entirely volatilized. In this manner its adulteration may be discovered.

The other metals may be reduced by themselves, and may be known by their own peculiar characters.—*Thomson's Annals*, No. lxi. p. 42, et seq.

1358. Although the principal analyses in the following sections have been conducted in the laboratory of the Royal Institution, and are therefore the results of actual experiment, there are many difficulties in their performance, which practice alone will enable the student to overcome, and some fallacies, to which, even with extensive experience, he will still find himself liable: among the latter, I cannot help adverting to those attractions of the metallic oxides for each other, which have been but little studied, but which often present serious difficulties to the proceedings of the analyst; where, for instance, several earths are held in the same solution, it is extremely difficult to effect their complete separation by the agency of those precipitants, which are generally regarded as throwing down only one of them; in the same way, although water occasions no precipitate in permuriate of tin, but throws down the oxide from permuriate of antimony, yet if the permuriates be mixed, it is found that the precipitate by water contains a very notable proportion of peroxide of tin; and many similar cases might be adduced.

The practice of submitting substances of known composition to analysis, cannot be too strongly recommended to the chemical student; it makes him acquainted with the mutual actions and habitudes of a number of bodies, which experience can alone teach, and gives a dexterity of manipulation, and an accuracy in conducting experimental inquiries, of which he will find the value when subsequently in the pursuit of original investigations.

SECTION I. *Of the Compounds of Potassium.*

1359. PURE POTASSA (544) should be perfectly soluble in twice its weight of water, and the solution should not effervesce upon the addition of a few drops of nitric acid, but remain undisturbed and transparent.

If nitric acid cause an effervescence in the solution of potassa, it indicates *carbonic acid;* if a precipitate not soluble in slight excess of the acid, it is *silica;* if a precipitate soluble in slight excess of acid, it is *alumina.*

The presence of *lime* in solution of caustic potassa is shown by neutralizing it by nitric acid, filtering if necessary, and adding oxalate of ammonia, which causes a white cloud; or, by the production of a precipitate of carbonate of lime upon adding solution of bi-carbonate of potassa.

Baryta water should occasion no turbidness in a solution of pure potassa; if it occasion a precipitate soluble with effervescence in nitric acid, it announces *carbonic acid;* if insoluble, *sulphuric acid.*

1360. *Chlorate of Potassa* (546) is sometimes mixed with a little of the *chloride of potassium,* which is shown by the addition of solution of nitrate of silver occasioning a precipitate, which it does not in the solution of the pure chlorate.

1361. *Nitrate of Potassa* (551).—The quantity of pure nitre in a given portion of the rough salt may be learned with tolerable accuracy by the following process:

Purification of Nitre.—7 lbs. of rough nitre are accurately weighed, and then dissolved by heat in 21 parts of water; when boiling, the scum is removed until no more rises, and then the solution is allowed to settle for ten minutes or longer. In this way nearly all the dirt falls down, and the clear solution being poured off, is passed through a filter of tow into a pan, and set aside to crystallize; the dirt left behind is added to the scum, and both being diluted, are filtered through paper, and the clear solution preserved. Next day the crystals formed in the pan are separated and put into funnels to drain, and the mother liquor with the filtered solution from the scum, *&c.*, are further evaporated and again left to crystallize. On the second evaporation, impurities generally separate from the solution; these are sometimes oxide of iron, or sulphate of lime, but most frequently common salt and nitrate of soda. The two first are easily separated by filtration; the third is best separated by evaporating the solution considerably, until much salt has been deposited, and then pouring the whole upon a filter of tow; the salt will remain on it, and should be washed by water to separate the nitre, which water should be added to the liquor, and the whole then brought to the crystallizing point. When cold, the crystals deposited by this solution are to be separated, and more salt separated as before, until the mother liquor is divided into common salt and nitre. It frequently happens that the crystals from the two or three last evaporations are coloured or contaminated by the adhesion of common salt, sulphate of lime, *&c.*;

in this case, they should be re-dissolved and re-crystallized with the same precautions as before. Care should be taken in drying the crystals, especially when small or when hastily formed, that no water remain in the interstices or cleavages between them.

Solution of pure nitre is not rendered turbid either by nitrate of silver or nitrate of baryta.

1362. *Gunpowder.*—To analyze this compound, boil it with four parts of water, edulcorate the residue, dry it at 212°, and weigh; the loss indicates the nitre. The dry residue, composed of charcoal and sulphur, may be decomposed by spreading it upon an earthen plate and burning off the sulphur at the lowest possible heat; the charcoal will remain, still however retaining a little sulphur. A more accurate process consists in introducing the mixture into a small retort furnished with a stopcock, exhausted, and filled with chlorine; heat applied volatilizes the chloride of sulphur and leaves the charcoal, which may be washed, dried, and weighed.

1363. *Carbonate of Potassa.*—Dr. Henry has given the following directions for ascertaining the quantity of real alcali contained in the rough alcalis of commerce; the process depends upon their saturating power in respect to an acid of known density, and the principle of the analysis has been already adverted to (569, 600); his directions, however, are of such practical utility, that I have, with his permission, transcribed them.

"Provide a tube, nine inches and a half long and three-fourths of an inch internal diameter, provided with a lip for the convenience of pouring, and a glass foot to support it.

" A tube of this kind holds 1000 grains of water, and (which is desirable) a little more. To graduate it, weigh into it 100 successive portions of distilled water at 60° Fahrenheit, of ten grains each ; or, if the tube be of equal bore throughout, it may be sufficient to weigh into it ten successive portions of water of 100 grains each, dividing each of the intermediate spaces into ten parts by a pair of compasses. When 1000 grains of water have been weighed into the tube, a line may be drawn with a file, which may be marked 0, the tenth below this 10, and so on.

" The test acid, which I prefer, is made by diluting one part of oil of vitriol of commerce of sp. gr. 1.849, with four parts of water ; consequently, one fifth part of its weight is concentrated oil of vitriol, and its specific gravity is, as nearly as possible, 1.141. Acid of this strength does not, on farther dilution, give out any heat, that can be a source of inaccuracy.

" When an alcali is to be examined, find, by Dr. Wollaston's Scale of Equivalents, how many grains of oil of vitriol are required to neutralize 100 grains of what may be considered the proper alcaline ingredient of the substance in question. This, in *pearlash,* is sub-carbonate of potash ; in *potash,* pure potash; in *barilla,* or *kelp,* dry sub-carbonate of soda. Let us take pearl-ash as an example. On referring to the scale, we find that 100 grains of sub-carbonate of potash are equivalent to 71 grains of concentrated oil of vitriol*. Put, therefore, into the test tube a quantity of the dilute acid containing 71 grains of concentrated acid,

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* Dr. Ure makes it 70.4.—*Journ. of Science,* iv. 119.

viz., 355 grains; and to spare the trouble, on any future occasion, of weighing the acid, let a line be drawn with a file on the blank side of the tube, at the level of the acid liquor, which may be marked *Equiv^t. of Subc. Pot.*

"Fill up the tube with water to the line marked 0, and mix the acid and water completely by pouring them into a lipped glass vessel; stirring with a glass rod; and then returning them into the tube. Now as the whole 100 measures contain a quantity of oil of vitriol equivalent to 100 grains of sub-carbonate of potash, it is obvious that each measure of the liquor in the tube is adequate to the neutralization of one grain of the sub-carbonate.

"Let 200 grains, taken out of a fair average specimen of the pearlash to be examined, be dissolved in two ounce measures of warm distilled water, filter the solution; and wash the filter with two ounces more of water, which is best applied to the margin of the paper, by means of a dropping bottle. Add the washings to the solution; and having mixed the whole together, pour one half into a tumbler or goblet, reserving the other half for a repetition of the experiment if necessary.

"To the liquor in the glass goblet, add the diluted acid very gradually, making the additions more and more slowly towards the last. As soon as the point of neutralization is attained, which will be shown by the cessation of a change of colour in slips of litmus and of turmeric paper dipped, from time to time, into the liquor, no more acid must be added. It is proper, however, the operator should be aware, that there will often be an apparent excess of test acid, in consequence of the carbonic acid, which is disengaged, acting on the litmus paper. To avoid this source of error, it is advisable, towards the last, to warm the liquor, by setting the glass containing it for half an hour near the fire, and while thus warmed, to add very cautiously the rest of the acid required for saturation. This point being attained, the number on the test-tube, at the level of the acid remaining in it, shews at once, without any calculation, how much *per cent.* of sub-carbonate of potash is contained in the pearlash under examination. In the samples, I have tried, it has generally been about 80 *per cent.*

"In operating on barilla, kelp, or any variety of the mineral alcali, the process is exactly the same, except that as 93* of oil of vitriol are equivalent to 100 of sub-carbonate of soda, we must take 93 × 5 = 465 grains, of sulphuric acid of density 1.141. This may be marked on the tube, *Equiv^t. of Subc. of Soda.* In a similar manner, we may mark on the tube the equivalent of *pure potash, viz.*, 520 grains of the above diluted acid; and that of *pure soda*, 783 grains; with any other equivalents, that may be likely to be of use.

"Having ascertained the proportion of subcarbonate of potash in any sample of pearlash, it is easy to find, by the sliding scale, its equivalent quantity of pure or caustic potash. Thus, supposing the pearlash to contain 80 *per cent.* of sub-carbonate, that number being set to

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* According to Dr. Ure, 91.4 is the true equivalent.—*Journ. of Science*, &c. iv. 119.

sub-carbonate of potash on the scale, the equivalent in pure potash is at once seen to be 55.

" To determine, by the same graduated tube, the strength of *any acid* whose equivalent is known, (which is the reverse of the foregoing process) we must put 100 grains of the acid, with a sufficient quantity of water, into a goblet; and use, for saturating it, its equivalent of any alcali. For example, 100 grains of concentrated oil of vitriol requiring for saturation 108 grains of dry sub-carbonate of soda, dissolve the latter quantity of alcali in water sufficient to make up 100 measures of solution in the tube; then pour the alcaline solution to the acid liquor, till the latter is neutralized; and the number of measures, which have been expended, exactly denote the strength of the acid.

" It may sometimes be desirable to know the proportion, not of concentrated or of real acid, but of acid of some inferior degree of density, in a specimen of acid. The method of doing this will best be explained by an example. Suppose that we wish to know the equivalent, in muriatic acid of sp. gr. 1.160, to 100 grains of the same acid of sp. gr. 1.074; find, by the alcaline test, or by referring to the tables in the Appendix, how much real acid 100 grains of both those acids contain. In acid of sp. gr. 1.160, it will be 23.4 *per cent.;* in acid of sp. gr. 1.074, it will be 11. Then 23.4 : 100 :: 11 : 47. Therefore 47 grains of muriatic acid, of sp. gr. 1.160, are equivalent, in acidity, to 100 of sp. gr. 1.074.

" No chemical operation can be more simple, or more easily managed, than the measurement of the strength of alcalis by acid liquors, and of acids by alcaline ones, in the way which has been described. The test-tube, which is the only instrument, required for that purpose, may be had at any glass-house, and may easily be graduated by any person who will take the necessary pains. When once accurately prepared, it will be found, also, useful for a variety of other purposes, which will readily present themselves to the practical chemist."

1364. The *purified Carbonate of Potassa* (569) of the shops should be perfectly soluble in twice its weight of cold water. It often contains *silica*, *sulphate of potassa*, *chloride of potassium*, and *carbonate of lime.* To detect these, dissolve a hundred grains in nitric acid diluted with eight parts of water; the silica, if any be present, remains undissolved: separate the solution into three equal parts; to the first, add nitrate of baryta, which causes a precipitate of sulphate; collect, wash, and dry it; 100 parts are equivalent to 74 of sulphate of potassa: to the second, add nitrate of silver; 100 grains of the precipitate, washed and dried at a dull red heat, is equivalent to 52 of chloride of potassium: to the third, add oxalate of ammonia, and dry the edulcorated precipitate at a heat of 300°; 100 parts are equal to 77 of carbonate of lime.

1365. There are a few mineral substances which contain potassa; it was first detected in the *leucite* by Klaproth, whose analysis of that mineral may be advantageously consulted by the student. (*Analytical Essays*, i. 348.) It consists of

Silica........	53.750
Alumina	24.625
Potassa	21.350
	99.725

There are two modes of analysis which may be practised upon such minerals; they may either be directly acted upon by acids: or fused with baryta, and afterwards submitted to acid solution.

A. 100 grains of leucite in very fine powder were digested for six hours in muriatic acid, which was then decanted off and the residue washed upon a filter, the washings being mixed with the solution. The residue weighed 60 grains. (*a.*)

B. The muriatic solution was supersaturated with pure ammonia, which occasioned a bulky brownish precipitate (*b*), which was collected, washed, and dried; it amounted to 12.5 grains.

C. Carbonate of ammonia produced no change in the last-mentioned filtrated liquor, which was therefore evaporated to dryness and the residue exposed to a red heat in a platinum crucible; it was then completely re-dissolved in water and again evaporated to dryness; it had the characters of chloride of potassium (*c*), and weighed 41 grains.

D. The residue *a* A was fused with three parts of potassa in a silver crucible, the fused mass dissolved in water, supersaturated with muriatic acid, evaporated to dryness, and again digested in water; there remained 58.5 grains of dry and pure silica.

E. The precipitate *b* B was entirely soluble in pure solution of potassa, with the exception of a trace of oxide of iron. Being again thrown down by muriate of ammonia, it was found to be pure alumina.

F. The chloride of potassium *c* c was decomposed in a platinum crucible by sulphuric acid, and it afforded 48 grains of sulphate of potassa, which is equivalent to 26 of potassa.

The result of this analysis differs in the proportions of the components from that of Klaproth; it may be stated as follows:

Silica, A *a*	58.5	grains
Alumina with a trace of iron } B *b* & E	12.5	
Potassa, C *c* F	26.	
Loss	3.	
	100.	

1366. It may here be remarked, that the existence of potassa, soda, and lithia in minerals, is generally first indicated by the great apparent loss which is sustained upon collecting and weighing their precipitable components: thus, if in any case of analysis we lose upon the aggregate weight of the precipitates, more than 2 or 3 *per cent.*, we may suspect the existence of the fixed alcalis, and direct our attention accordingly to their detection. It also generally happens, that minerals which contain any considerable proportion of fixed alcaline substances, are remarkable for the facility with which they enter into fusion before the blowpipe.

SECTION II. *Of the Combinations of Sodium.*

1367. *Pure Soda* (577) may be tested in the same way as pure potassa. The presence of *potassa* in soda may be detected by adding to its aqueous solution muriate of platinum, which forms a buff-coloured precipitate if potassa be present.

1368. *Chloride of Sodium.* (579). The usual impurities of sea-salt are *muriates of magnesia and lime.* Dissolve 100 grains in an ounce of water, and add carbonate of ammonia, which throws down carbonate of lime, 100 parts of which, washed and dried at 300°, are equivalent to 110 of dry muriate of lime (chloride of calcium). Boil the filtered liquor nearly to dryness, and carbonate of magnesia falls, of which 100 parts are equal to about 134 of dry muriate of magnesia.

1369. *Sulphate of Soda.*—This salt in the form of crystals, may be analyzed as follows: Weigh off 100 grains, and introduce it into a platinum crucible, previously weighed; place it in a sand heat, and gradually give it a red heat for half an hour; when cold ascertain the loss of weight, which is water of crystallization. (*a*). Pour two ounces of water upon the dry salt, and when perfectly dissolved add solution of nitrate of baryta as long as it occasions any precipitate; edulcorate, dry, and weigh the sulphate of baryta thrown down (*b*), of which 100 parts indicate 34 of sulphuric acid. The filtered liquor contains the soda, now in the state of nitrate, and any excess of nitrate of baryta that might have been added: evaporate it to dryness, expose the residue to a red heat for half an hour in a platinum crucible, by which the acid will be expelled, and a mixture of soda and baryta remain; pour upon it dilute sulphuric acid, which forms sulphate of soda and sulphate of baryta; the latter, being insoluble, is separated by filtration; the filtered solution of regenerated sulphate of soda should afford on evaporation and expulsion of water as above directed, a quantity of sulphate, exactly equal to that of the process, (*a*). Thus it will be found that 100 grains of sulphate of soda in crystals, afford of

Water	56.00
Sulphuric acid	24.75
Soda	19.25

1370. Sulphate of soda is seldom sophisticated; it should not change the colour of litmus or turmeric; it sometimes contains a little iron, which interferes with some of its pharmaceutical uses; this may be detected by adding tincture of galls to the aqueous solution of the salt, slightly acidulated by nitric acid, when it occasions a black cloud. Sea salt is discovered in solution of sulphate of soda, by the addition of sulphate of silver; salts of lime are shown by the precipitate of carbonate of lime, occasioned by carbonate of ammonia. Sulphate of potassa is recognised by its sparing solubility.

1371. *Carbonate of Soda.*—The analysis of kelp and barilla has been above referred to. (page 356.)

The carbonate of soda of the shops *(sodæ subcarbonas* of the *Pharmacopæia),* often contains *sulphate of soda* and *sea salt ;* to discover these, saturate a given weight of the salt with pure dilute nitric acid, and divide the solution into two parts : to one add nitrate of baryta, which gives a precipitate of sulphate of baryta ; to the other add nitrate of silver, which throws down chloride of silver, of which 100 parts, properly washed and dried, are equal to 41 of sea salt.

If carbonate of soda contain *carbonate of potassa,* its presence is shown by adding to a saturated solution of the carbonate, a saturated solution of tartaric acid *in excess ;* a precipitation of crystalline grains of bi-tartrate of potassa ensues if potassa be present.

1372. *Bi-carbonate of Soda* is frequently mixed with carbonate of soda ; and it is difficult to detect the proportion of the latter, in consequence of the quantity of water in the bi-carbonate, not having been accurately ascertained. The composition of the dry bi-carbonate is given above. (601).

1373. *Borate of Soda,* or borax, is sometimes adulterated by common salt, and by alum. To detect these, dissolve a portion of the salt in water, and add slight excess of nitric acid. Test this solution by nitrate of silver for the discovery of sea salt ; and by nitrate of baryta for sulphuric acid.

1374. There are several minerals which contain soda ; the following analysis of the sodalite, by Dr. Thomson, may be taken as an instance of one mode of proceeding in these cases.—*Phil. Mag.*, xxxvii. p. 303 ; or, *Transactions of the Royal Society of Edinburgh.*

" 100 grains of the mineral, reduced to a fine powder, were mixed with 200 grains of pure soda, and exposed for an hour to a strong red heat in a platinum crucible.

The mixture melted, and assumed, when cold, a beautiful grass-green colour. When softened with water, the portion adhering to the sides of the crucible, acquired a fine brownish yellow. Nitric acid being poured upon it, a complete solution was obtained. Suspecting from the appearance which the fused mass assumed, that it might contain chromium, I neutralized the solution as nearly as possible with ammonia, and then poured into it a recently prepared nitrate of mercury. A white precipitate fell, which being dried and exposed to a heat rather under redness, was all dissipated, except a small portion of gray matter, not weighing quite 0.1 grain. This matter was insoluble in acids, but became white. With potash it fused into a colourless glass. Hence I consider it as silica. This experiment shews that no chromium was present. I was at a loss to account for the precipitate thrown down by the nitrate of mercury. But Mr. Allan having shewn me a letter from Ekeberg, in which he mentions that he had detected muriatic acid in sodalite, it was easy to see that the whole precipitate was calomel. The white powder weighed 26 grains, indicating, according to the analysis of Chenevix, about 3 grains of muriatic acid.

" The solution, thus freed from muriatic acid, being concentrated by evaporation, gelatinized. It was evaporated nearly to dryness, the dry mass digested in hot water, acidulated with nitric acid, and poured upon the filter, was washed, dried, and heated to redness. It weighed 37.2 grains, and was silica. The liquor which had passed through the filter was supersaturated with carbonate of potash, and the copious white precipitate which fell, collected by the filter, and boiled, while yet moist, in potash-ley. The bulk diminished greatly, and the undissolved portion assumed a black colour, owing to some oxide of mercury with which it was contaminated. The potash-ley being passed through the filter, to free it from the undissolved matter, was mixed with a sufficient quantity of sal-ammoniac. A copious white precipitate fell, which being collected, washed, dried, and heated to redness, weighed 27.7 grains. This powder being digested in sulphuric acid, dissolved except 0.22 grain of silica. Sulphate of potash being added, and the solution set aside, it yielded alum crystals to the very last drop. Hence the 27.48 grains of dissolved powder were alumina.

" The black residue, which the potash-ley had not taken up, was dissolved in diluted sulphuric acid. The solution being evaporated to dryness, and the residue digested in hot water, a white soft powder remained, which, heated to redness, weighed 3.6 grains, and was sulphate of lime, equivalent to about 2 grains of lime.

" The liquid from which the sulphate of lime was separated, being exactly neutralized by ammonia, succinate of ammonia was dropped in, a brownish red precipitate fell, which being heated to redness in a covered crucible, weighed 1 grain, and was black oxide of iron.

" The residual liquor being now examined by different re-agents, nothing further could be precipitated from it. The liquid from which the alumina, lime, and iron, had been separated by carbonate of potash, being boiled for some time, let fall a small quantity of yellow coloured matter. This matter being digested in diluted sulphuric acid, partly dissolved with effervescence, but a portion remained undissolved, weighing 1 grain. It was insoluble in acids, and with potash melted into a colourless glass. It was therefore silica. The sulphuric acid solution being evaporated to dryness, left a residue which possessed the properties of sulphate of lime, and which weighed 1.2 grains, equivalent to about 0.7 grain of lime.

" The constituents obtained by the preceding analysis being obviously defective, it remained to examine whether the mineral, according to the conjecture of Bournon, contained an alcali. For this purpose 100 grains of it, reduced to a fine powder, and mixed with 500 grains of nitrate of barytes, were exposed for an hour to a red heat in a porcelain crucible. The fused mass was softened with water, and heated with muriatic acid. The whole dissolved except 25 grains of a white powder, which proved on examination to be silica. The muriatic acid solution was mixed with sulphuric acid, evaporated to dryness, the residue digested in hot water, and filtered to separate the sulphate of barytes. The liquid was now mixed with an excess of carbonate of ammonia, boiled for an instant or two, and then filtered, to separate the earth and iron precipitated by the ammonia. The liquid was evaporated to dryness, and the dry mass obtained exposed to a red heat in a silver crucible. The residue was dissolved in water, and exposed in the open air to spontaneous evaporation. The whole gradually shot into regular crystals of sulphate of soda. This salt being exposed to a strong red heat, weighed 50 grains, indicating, according to Berthollet's late analysis, 23.5 grains of pure soda. It deserves to be mentioned, that during this process the silver crucible was acted on, and a small portion of it was afterwards found among the sulphate of soda.

" This portion was separated before the sulphate of soda was weighed.

" The preceding analysis gives us the constituents of sodalite as follows:

Silica	38.52
Alumina	27.48
Lime	2.70
Oxide of iron	1.00
Soda	23.50
Muriatic acid	3.00
Volatile matter	2.10
Loss	1.70
	100.00

" Mr. Allan sent a specimen of this mineral to Mr. Ekeberg, who analyzed it in the course of last summer. The constituents which he obtained, as he states them in a letter to Mr. Allan, are as follows:

Silica	36.
Alumina	32.
Soda	25.
Muriatic acid	6.75
Oxide of iron	0.25
	100.00

" This result does not differ much from mine. The quantity of muriatic acid is much greater than mine. The lime and the volatile matter which I obtained escaped his notice altogether. If we were to add them to the alumina it would make the two analyses almost the same. No mineral has hitherto been found containing nearly so much soda as this. Hence the reason of the name by which I have distinguished it."

SECTION III. *Of the Combinations of Lithium.*

1375. LITHIUM (607) has been found in a very few minerals only. It is contained in largest quantity in the *triphane* or *spodumene*, which consists of

Silica	66.
Alumina	25.
Lithia	9.
A trace of oxide of iron.	
	100.

Triphane has been found in Sweden, in the Tyrol, and in Ireland. Its colour is grayish green; it is translucent, hard, and brittle: sp. gr. 3.2. It occurs massive, and its structure is lamellar, and fibrous.

Petalite, according to the corrected analysis of M. Arfwedson, consists of

Silica	77.
Alumina	17.
Lithia	6.
	100.

Petalite has hitherto been found in Sweden only; its colours are reddish, greenish, or grayish white. It is translucent, lamellar, and hard: sp. gr. 2.6.

1376. These minerals may be analyzed by the following process:

Reduce 50 grains, in an agate or steel mortar, to a very fine and impalpable powder, and mix it with thrice its weight of precipitated carbonate of baryta; give the mixture a red heat for an hour in a silver crucible, wash out the contents, add a small excess of muriatic acid, and evaporate to dryness; boil the dry residue in 12 parts of water, and filter when cold; the silica will remain on the filter, and may be washed, ignited, and weighed.

The filtered liquor (*a*) holds the muriates of baryta, alumina, iron, and lithia: add solution of sulphate of ammonia as long as it occasions a precipitate, which separate, and wash, adding the washings to the filtered liquor (*b*); the baryta is thus removed in the state of sulphate.

To the filtered solution (*b*) add carbonate of ammonia, to throw down the alumina and iron, which collect, and wash, adding the washings to the third filtered liquor (*c*). The mixed precipitate of alumina and oxide of iron may be digested in potassa, which takes up the former, leaving the oxide of iron to be collected, washed, ignited, and weighed.

Evaporate the filtered solution (*c*) to dryness, and ignite the residuum in a silver crucible; the ammoniacal salts are driven off, and pure chloride of lithium remains, from which the lithia may be obtained by carbonate of silver, as above stated (607).

SECTION IV. *Of the Combinations of Calcium.*

1377. FOR the manufacture of mortar, lime should be entirely free from carbonic acid, the presence of which is ascertained by the effervescence occasioned on adding muriatic acid to a portion of the lime slaked in, and diffused through, water.

1378. To ascertain the quantity of carbonic acid in carbonate of lime, or other carbonate, proceed as follows: Provide a thin light phial, capable of holding about six ounces, with a mouth of half an inch diameter; pour into this phial one ounce of nitric acid, diluted with its bulk of water, taking care not to soil the neck; stop it with a plug of cotton wool, and counter-balance the whole in the scale of a delicate beam. Having now weighed off 100 grains of the carbonate, place a hundred grain weight in the scale with the counterpoise, and carefully introduce the carbonate, broken into pieces, into the acid; stop the phial loosely with the wool, and suffer the carbonate to dissolve; during this operation the carbonic acid will escape through the cotton plug, which prevents any particles of liquid being thrown out during the effervescence, and the counterpoise scale will preponderate in consequence of the loss of weight sustained by the carbonate from the evolution of its carbonic acid. When the solution is complete, open the phial, and blow through it by a glass tube, so as to displace the included atmosphere; replace the plug, and bring the balance to an equipoise by adding weights to the scale containing the phial, which weights will show the quantity of carbonic acid lost by 100 grains of the carbonate. If pure carbonate of lime be employed, the loss will amount to 44 grains.

1379. We will suppose, however, that a limestone has been operated on not perfectly soluble in the acid, and containing magnesia and alumina; the other steps of the analysis are as follow:

The insoluble portion must be separated by decantation, collected upon a filter, washed and dried, the washings being added to the original solution. It is probably silica.

The solution we will suppose to contain lime, magnesia, and alumina; to separate these earths, add carbonate of potassa in very slight excess; boil the mixture, collect and wash the precipitate, which will consist of the carbonates of lime and magnesia, and alumina; digest it while moist in solution of pure potassa, which dissolves out the alumina; pour the whole upon a filter, washing the insoluble portion, and add to the filtered liquid (which is the alcaline solution of alumina) a slight excess of oxalic acid; collect, wash, and dry the precipitate, at a red heat, in a platinum crucible, and weigh it; it is pure alumina. The separation of the magnesia and lime may be effected by the process above described (699).

1380. The analysis of *sulphate of lime* (633) may be effected by an alcaline carbonate as follows:

Reduce 50 grains of the sulphate to a very fine powder, and boil it for half an hour in a Florence flask, with 100 grains of carbonate of soda, dissolved in four ounces of water; the lime will thus be converted into carbonate, which, collected upon a filter, washed, and dried at 500°, will give either by inference, or analysis, the proportion of lime.

The filtered solution will contain the sulphuric acid of the sulphate, the quantity of which may be learned by adding muriate of baryta, and digesting the precipitate in dilute muriatic acid, to remove any carbonate of baryta; the insoluble residuum, washed and duly dried, gives the equivalent of the sulphuric acid.

The proportion of water of crystallization in the sulphates of lime, may be arrived at by exposing 100 parts in fine powder, to a red heat; the loss indicates the quantity of water *per cent.*

1381. The analysis of a mixture of carbonate and phosphate of lime may be performed in the following manner:

Dissolve in dilute nitric acid, and add pure ammonia to the solution, which causes a precipitate of phosphate of lime, equivalent, when dry, to that existing in the original mixture.

Having separated the phosphate by filtration, add carbonate of ammonia, which throws down carbonate of lime; collect, wash, and dry it.

1382. It is generally supposed that the quantity of acid and of base in phosphate of lime may be learned by the following process: Dissolve 50 grains of the phosphate in as small a quantity as will take it up of nitric acid, diluted with its bulk of water: to this solution add oxalate of ammonia, which will cause a precipitate of oxalate of lime, which may be separated, ignited to whiteness, and weighed: it gives the pure lime.

Phosphate of ammonia is retained in the solution, which, evaporated to dryness, and heated red hot in a platinum crucible, gives pure phosphoric acid: or, the solution may be decomposed by the addition of nitrate of lead; which gives an insoluble phosphate of lead, of which 100 parts indicate about 20 of phosphoric acid. But phosphate of lime is only partially decomposed by oxalate of ammonia and nitrate of lead. Phosphate of lime boiled with carbonate of potassa, gives rise to the production of carbonate of lime and phosphate of potassa.

1383. No accurate analysis has hitherto been made of *fluor spar* (646); and we are ignorant of the nature of the colouring principle of the blue variety; it fades by exposure to light, and is destroyed by a heat below redness. When 100 grains of pure and colourless fluor spar, previously heated red hot, are boiled to dryness in a silver crucible, with 200 of sulphuric acid, and the dry mass exposed to a red heat, 190 parts of dry sulphate of lime are obtained, equivalent to about 78 of lime. If we regard fluor spar as a fluoride of calcium, the 78 of lime being equivalent to 56 of calcium, would give the composition of that substance

56 calcium
44 fluorine

and 56 : 44 :: 19 : 14.98. Upon this datum the number 15 has been above adopted as the representative of fluorine.

1384. The number 26.5, as the equivalent of lime, is that given by Dr. Wollaston in his valuable observations upon the synoptic scale of chemical equivalents, and regarding it as containing one third the quantity of oxygen existing in the proportion of sulphuric acid that combines with it to form sulphate of lime, the number 19 may be regarded as the correct equivalent of calcium.

SECTION V. *Of the Compounds of Barium.*

1385. BY dissolving 100 grains of *native carbonate of baryta* (648), previously dried at a red heat, in muriatic acid, with the precautions above-directed (1377), they will be found to lose 22 grains of carbonic acid; hence the carbonate consists of

Baryta	78
Carbonic acid	22
	100

If we now precipitate the muriatic solution by carbonate of ammonia, collect the precipitate and dry it at a dull red heat, we shall find it to weigh 100 grains, showing that the composition of the native and artificial carbonate is similar.

If we precipitate the muriatic solution by dilute sulphuric acid, the precipitate of sulphate of baryta properly dried weighs 118 grains; hence the artificial sulphate is composed of

Baryta	78	=	66
Sulphuric acid	40		34
	118		100

100 grains of carbonate of baryta dissolved in nitric acid, evaporated to dryness, and exposed for half an hour to a red heat, gave 78 grains of pure baryta.

1386. These results, which closely agree with the original analyses of Dr. Withering (*Phil. Trans.*, 1784.) and of Klaproth, (*Analytical Essays*, i.) furnish the number 72.8 as the representative of baryta, for in respect to the sulphate, 40 : 78 :: 37.5 : 72.8. The number 72.5, above adopted as the equivalent of baryta, is the mean of three analyses, and probably very near perfect correctness. Deducting from this number one third of the weight of the oxygen in sulphuric acid = 7.5, gives 65 as the theoretical equivalent of barium.

1387. The only compound mineral hitherto discovered containing baryta, is the harmotome or cross-stone; in that from Andreasberg, Klaproth found

Silica	49
Alumina	16
Baryta	18
Water	15
	98

The analysis of this compound may be made by fusing it in fine powder with potassa, solution in muriatic acid, and evaporation to dryness; pour water upon the dry mass, which leaves silica; to the solution add sulphate of ammonia, which throws down the baryta in the state of sulphate; separate it by a filter, evaporate the filtered liquor to dryness, and give it a red heat; re-dissolve the dry residue in water, and add ammonia, which throws down alumina.

SECTION VI. *Of the Compounds of Strontium.*

1388. The analysis of the *sulphate* and *carbonate of strontia* may be performed in the same way as that of the corresponding compounds of baryta.

1389. Strontia has been found by Mr. Stromeyer in some varieties of *arragonite* (643), and where it exists in small proportion with carbonate of lime, its presence is not easily detected.

I dissolved 5 grains of carbonate of strontia and 95 of carbonate of lime in nitric acid; added sulphate of ammonia to the solution, collected the precipitate, and washed it with repeated affusions of hot water; when dry, it weighed 6.3 grains, and was sulphate of strontia. Ignited with half its weight of charcoal, and digested in dilute muriatic acid, it afforded a solution of muriate of strontia, the properties of which are easily distinguished from those of muriate of baryta (669).

1390. The number 44.5 as the equivalent of strontium, and 52 as that of strontia, are deduced from the analyses of the sulphate and of the carbonate.

SECTION VII. *Of the Compounds of Magnesium.*

1391. WHEN 100 parts of pure *crystallized sulphate of magnesia* are exposed to a red heat for one hour, they lose, upon the average of several experiments, 52 *per cent.* of water of crystallization; the residue is perfectly soluble in water, and consequently no acid has been expelled: if to its aqueous solution we add muriate of baryta, and collect and dry the precipitate, it will be found to indicate 32.5 of sulphuric acid; hence the composition of the crystallized salt; and

$$32.7 : 16.3 :: 37.5 : 18.6.$$

Hence the number 18.5 adopted as the representative of magnesia, and 11 as the theoretical equivalent of its metallic base.

1392. Besides the adulteration of sulphate of magnesia with sulphate of soda, already adverted to, the salt as it occurs in commerce is often deliquescent from the presence of muriate of lime, and muriate of magnesia: the presence of muriatic acid is shown by sulphate of silver; and of lime, by oxalate of ammonia, or by bi-carbonate of ammonia, which does not throw down magnesia. Sea salt is not unfrequently found in considerable proportion, mixed with sulphate of magnesia, and which is not thus rendered deliquescent: it is recognised by its salt taste, by the action of sulphate of silver, and by pouring sulphuric acid upon it, which disengages muriatic vapours, easily known by the dense white fumes occasioned by holding a stopper moistened with liquid ammonia above the salt.

I have sometimes found amongst Epsom salt a very considerable proportion of the triple sulphate of magnesia and potassa. (687). It is known by its sparing solubility, and by the rhomboidal form of its crystals:

it occasions a grittiness in the mouth, and is less bitter than sulphate of magnesia.

1393. *Carbonate of magnesia* (693), when precipitated in the usual way and dried at 212°, always retains a portion of water, which it loses by exposure to a red heat along with its carbonic acid; the water thus retained varies from 16 to 21 *per cent.* Lime is a very common impurity both in carbonate and calcined magnesia, being frequently derived from sulphate of lime contained in the water used for edulcorating the precipitated carbonate. To the calcined magnesia it gives an acrid alcaline taste. The presence of lime is detected by dissolving the magnesia or its carbonate in muriatic acid, and adding solution of bi-carbonate of ammonia, which throws down carbonate of lime, but does not affect a pure magnesian solution. When carbonate of lime is fraudulently added to carbonate of magnesia, as is sometimes the case, it is detected in the same way.

The separation of lime and magnesia, when present in the same solution, has already been adverted to (699).

1394. The analysis of mineral substances containing magnesia may in some cases be performed in the humid way; but where the stone resists the action of acids, fusion with alcaline bodies must be resorted to. As instances of these analyses, the reader is referred to Klaproth's examination of the chrysolite and of olivin, in the seventh and eighth sections of the first volume of his *Analytical Essays.* The following instances may serve further to illustrate the separation of magnesia in cases of complex chemical analysis.

A. 100 parts of red and green-veined primitive *serpentine* were exposed to a dull red heat for half an hour, and were found to have lost 6 grains.

B. The remaining 94 grains, reduced to fine powder, were digested in muriatic acid diluted with two parts of water, and when it no longer acted upon the residue it was decanted off, the residue washed, and the washings added to the muriatic solution. The undissolved portion, when dried at a red heat, weighed 38 grains, and had the properties of pure silica.

C. The muriatic solution supersaturated with liquid bi-carbonate of ammonia afforded a brown precipitate, which was collected, washed, and dried; it weighed 25.5 grains, and was found to contain no alumina; it dissolved entirely and with effervescence in muriatic acid, and this solution was evaporated to dryness, the dry residue dissolved in water, and this solution precipitated by oxalate of ammonia, yielded oxalate of lime, which collected and ignited to whiteness afforded 13 grains of pure lime: the liquor from which this oxalic precipitate had been obtained left after evaporation and ignition 2.5 grains of red oxide of iron, equivalent to about 2.2 grains of the black oxide, in which state the metal probably exists in serpentine.

D. The solution from which the precipitate noticed in the last paragraph had been separated, was next evaporated to dryness, and the residue exposed to a red heat in a platinum capsule, till it ceased to lose weight; in this way 40 grains of magnesia slightly tinged by an inappreciable portion of oxide of iron were obtained.

E. It accordingly appears from the above analysis, that 100 parts of precious serpentine contain

A.	Water	6. grains
B.	Silica	38.
C.	Lime	13.
	Oxide of iron	2.2
D.	Magnesia	40.
	Loss	.8
		100

Another specimen of serpentine, from the Lizard, lost 7 grains of water by heat; (*a*) digested in muriatic acid, it gave 43.5 grains of silica; (*b*) the muriatic solution was saturated with carbonate of ammonia, filtered and evaporated to dryness; the dry residue, after having been heated red-hot, gave 30.7 grains of magnesia; (*c*) upon the filter there remained a precipitate of a brown colour, which was dissolved in muriatic acid; pure ammonia added to this solution, gave a precipitate weighing 13 grains, and resolved by potassa into 10 grains of peroxide of iron = 9 protoxide, and 3 grains of alumina. (*d*) The muriatic solution, after the separation of the precipitate by pure ammonia, gave, on adding carbonate of ammonia, 5.3 grains of carbonate of lime = 3 grains of lime. This specimen, therefore, of serpentine, was composed of

	Water	7.0
a	Silica	43.5
b	Magnesia	30.7
c	Oxide of iron	9.0
c	Alumina	3.0
d	Lime	3.0
		96.2

1395. There are some magnesian stones, such for instance as the chrysolite and the olivin, which are so hard as to resist to a considerable extent, even when pulverized, the action of muriatic acid: in conducting their analysis, they should be previously fused with potassa. If alumina be present, it may be thrown down from the muriatic solution together with the lime, by carbonate of ammonia, and afterwards separated by the action of solution of potassa.

SECTION VIII. *Of the Compounds of Manganese.*

1396. THE *grey radiated ore of manganese* (703), when digested in fine powder in muriatic acid, is entirely dissolved, with the exception of a small but variable portion of silica, not exceeding 3 to 4 *per cent.*

The solution contains manganese with a small quantity of iron, which may be very conveniently separated by the action of ammonia, as recommended by Mr. Hatchett, and which, if added so as to saturate the muriatic acid, throws down the iron, but not the manganese.

The oxide of iron may be separated by filtration, and ignited with a little wax, which, when burned off, leaves protoxide of iron.

The filtered solution may be evaporated to dryness, and the residue moistened with nitric acid, and again evaporated and ignited: it is peroxide of manganese, the state probably in which the metal exists in the above ore.

1397. Manganese, as has been shown by Mr. Faraday, (*Quarterly Journal*, vi. 357,) readily forms triple salts with ammonia, and as these salts are not affected by the fixed alcalis, they are often conveniently formed in those analytical operations the object of which is to separate manganese from other metals: Upon this principle he proposes the following method of decomposing a mixed salt of manganese and iron. To a mixed solution of iron and manganese, add solution of muriate, sulphate, or nitrate of ammonia, and then pour in pure potassa; the iron will be precipitated immediately, but the manganese will remain in solution as a triple salt, unaffected by the free alcalis.

In this method of analysis the muriate or sulphate of ammonia is preferable to the nitrate, because the latter may in some cases produce peroxide of manganese, which would be precipitated; the quantity of ammoniacal salt added should, for the sake of security, be about twice that of the salt of manganese in solution, and as protoxide of iron is soluble in ammonia, any excess of that alcali should be driven off by heat, to ensure a total precipitation.

1398. The black oxide of manganese, as it occurs in commerce, is very often adulterated with chalk, which is detected by digesting a given weight of it in nitric acid diluted with 10 parts of water; if the oxide be pure, the acid thus diluted is without any immediate action; if it contain carbonate of lime, an instant effervescence ensues, and a nitrate of lime is formed, which may afterwards be decomposed by carbonate of potassa, and the weight of the precipitate when dry shows the quantity of the carbonate present.

SECTION IX. *Of the Compounds of Iron.*

1399. THE assay of those native oxides of iron which are the sources of the pure metal, may be performed as follows: reduce the ore to a very fine powder, and mix it with its weight of powdered green-bottle glass, half its weight of chalk, and one fourth of charcoal; expose this mixture to the full heat of a wind furnace for about an hour; suffer the crucible to cool slowly, and on breaking it, a button of metal will be found at the bottom, covered by the other materials, fused into a dense slag. If the ore contain any mixed pyrites, it should be previously roasted in a muffle or reverberatory furnace.

1400. The analysis of the *magnetic, specular,* and *hæmatitic oxides of iron* (725) is sufficiently simple, and may be accomplished in the following manner:

a. Reduce the ore to a very fine powder, and mix it in a silver crucible with three or four parts of liquid potassa; evaporate to dryness, and expose the residue for about 15 minutes to a dull red heat; when cold, reduce it to powder and dissolve in muriatic acid, evaporate nearly to dryness, and boil the residue in water; the silica remains, and may be separated by filtration. (*b*) The filtered solution of permuriate of iron may now be evaporated to a small bulk, and decomposed by potassa, which added in excess and boiled upon the precipitate, leaves peroxide of iron, and which having been washed, dried, and ignited with wax, is restored to the state of protoxide. (*c*) The filtered alcaline liquor now retains alumina, if any were present, which may be thrown down by muriate of ammonia, washed, and dried.

It sometimes happens that manganese is present in the muriatic solution *b*, and that it is thrown down with the oxide of iron: if this be the case, re-dissolve the precipitate, after its treatment by alcali, in muriatic acid, and *neutralize* by ammonia, which throws down the oxide of iron, but retains that of manganese; then proceed as directed in paragraph 1405.

1401. *Chloride of iron* (727) was analyzed as follows: (*a*) 100 grains were dissolved in water, and the solution decomposed by ammonia afforded a precipitate, which when washed, dried, and ignited with wax, was black oxide of iron, weighing 56.5 grains, and equivalent to 44 grains of metallic iron. (*b*) The filtered solution from which the oxide of iron had been separated was neutralized by nitric acid; nitrate of silver was then added, and the precipitated chloride of silver being collected and ignited weighed 227 grains, which is equivalent to 56 grains of chlorine; hence it appears that protochloride of iron consists of

44	iron
56	chlorine
100	

By a similar process, the perchloride of iron may also be analyzed.

1402. The native sulphuret of iron, or *magnetic pyrites* (737), was examined by Mr. Hatchett in the following way (*Phil. Trans.*, 1804.):

A. 100 grains, reduced to a fine powder, were digested with 2 ounces of muriatic acid, in a glass matrass placed in a sand-bath. A pale yellowish-green solution was formed. The residuum was then again digested with two parts of muriatic acid, mixed with one of nitric acid; and a quantity of pure sulphur was obtained, which, being dried, weighed 14 grains.

B. The acid in which the residuum had been digested, was added to the first muriatic solution; some nitric acid was also poured in, to promote the oxidizement of the iron, and thereby to facilitate the precipitation of it by ammonia, which was added after the liquor had been boiled for a considerable time. The precipitate thus obtained was boiled with lixivium of potash; it was then edulcorated, dried, made red-hot with wax in a covered porcelain crucible, was completely taken up by a magnet, and, being weighed, amounted to 80 grains.

C. The lixivium of potash was examined by muriate of ammonia, but no alumina was obtained.

D. To the filtrated liquor from which the iron had been precipitated by ammonia, muriate of barytes was added, until it ceased to produce any precipitate; this was then digested with some very dilute muriatic acid, was collected, washed, and, after exposure to a low red heat for a few minutes in a crucible of platina, weighed 155 grains. If therefore the quantity of sulphur, converted into sulphuric acid by the preceding operations, and precipitated by barytes, be calculated according to the accurate experiments of Mr. Chenevix, these 155 grains of sulphate of barytes will denote, nearly, 22.50 of sulphur; so that, with the addition of the 14 grains previously obtained in substance, the total quantity will amount to 36.50.

E. Moreover, from what has been stated it appears, that the iron which was obtained in the form of black oxide, weighed 80 grains; and, by adding these 80 grains to the 36.50 of sulphur, an increase of weight is found = 16.50. This was evidently owing to the oxidizement of the iron, which, in the magnetical pyrites, exists quite, or very nearly, in the metallic state, but, by the operations of the analysis, had received this addition. The real quantity of iron must, on this account, be estimated at 63.50.

100 grains, therefore, of the magnetical pyrites, yielded,

$$\begin{array}{lll} \text{Sulphur} & \left\{\begin{array}{ll} \text{A.} & 14. \\ \text{D.} & 22.50 \end{array}\right\} & 36.50 \text{ grains.} \\ \text{Iron} & \quad\text{E.} \quad = & \underline{63.50} \\ & & 100. \end{array}$$

The other varieties of pyrites were analyzed precisely in the same way.

1403. 100 parts of *crystallized protosulphate of iron* were analyzed as follows, in the laboratory of the Royal Institution. (*a*) The salt was reduced to powder, and dissolved in a small quantity of nitric acid; the solution was diluted, supersaturated by ammonia, and filtered. In this way the iron was separated in the state of peroxide, amounting to 28.5 grains, equivalent to 25.5 of protoxide of iron. (*b*) The filtered solution, now perfectly free from iron, but containing excess of ammonia, was neutralized by nitric acid, and nitrate of baryta was added till it ceased to form a precipitate. The sulphate of baryta thrown down was dried at a red heat and weighed 85 grains, indicating 28.7 of sulphuric acid: hence it appears that 100 grains of crystallized protosulphate of iron contain

25.5	protoxide of iron
28.7	sulphuric acid
54.2	

The loss, amounting to 45.8, is to be attributed to water of crystallization, for 100 grains of the crystals heated to dull redness for a quarter of an hour lose about 45 *per cent.*; hence the salt consists of

54.2	dry sulphate of iron
45.8	water of crystallization
100.	

The data upon which the composition of oxides of iron is founded, are given in paragraph 724.

1404. The analysis of *phosphate of iron* may be performed as that of phosphate of copper, which is given in Section 855.

1405. The analysis of the different kinds of iron produced by the manufacturer is attended with many difficulties, and has hitherto only been partially performed: on this subject some useful and interesting details will be found in Mr. Daniel's paper "On the mechanical structure of iron, *&c.*"—*Quarterly Journal of Science and Arts*, ii. 278.

1406. *Wootz* or *Indian steel* was examined in the laboratory of the Royal Institution by Mr. Faraday, as follows, with a view to detect its components, exclusive of carbon and iron.

A piece of wootz, weighing 164.3 grains, was placed in a flask, and acted on by nitro-muriatic acid and heat. It gradually dissolved, and dark-coloured flakes, separated from it, which were unalterable in the acid, though boiled with it. When all action had ceased, the solution was poured off from the sediment (*a*) which was repeatedly washed with distilled water; the solution was then examined carefully, but I could find nothing in it but iron. Whilst washing the sediment (*a*) it separated into two parts; a black powder (*b*) sank to the bottom of the water poured upon it, whilst a reddish brown substance (*c*) in flocculi remained suspended; these were parted from each other.

The black powder (*b*) was fused with potash in a silver capsule, and then dissolved in water; it deposited a brown powder (*d*), and a clear alcaline solution was obtained. This was saturated with muriatic acid, and evaporated to dryness, and then being re-dissolved with a little excess of muriatic acid, a very small quantity of white flocculi were left untouched, which were insoluble in acids, and had the characters of *silex*. The solution acted on by subcarbonate of potash give an abundant precipitate. This was washed, and when heated with a little solution of potash, dissolved in it like *alumine*. Sulphuric acid was then added, and a solution of alum was obtained, a small quantity of silex precipitating.

The brown powder (*d*) deposited by the alcaline solution, was treated with nitric acid; a little heat being applied, nearly the whole was dissolved immediately, leaving a little of a black substance. The filtered solution gave a precipitate with muriate of soda, but when ammonia was added to it, the precipitate was re-dissolved, and a small quantity of iron was thrown down. The solution contained, therefore, *silver*, from the capsule in which the fusion had been made, and *iron* derived from the wootz. The black substance left by the nitric acid, was nearly all dissolved, by nitro-muriatic acid, iron being taken into solution, and a little of the substance (*b*) remaining.

The reddish brown substance (*c*) was not affected by nitric acid, but, on adding solution of pure potash to it, a clear deep brown solution was obtained, and a blackish brown sediment (*e*) remained. When the alcali of the solution was neutralized by muriatic acid, flocculi, were precipitated, and the solution became colourless. These flocculi, collected together and dried, proved to be combustible, and appeared to be merely modified tannin. The brown sediment (*e*) being then examined by muriatic acid, gave oxide of iron and a little *silex.—Quarterly Journal of Science and Arts*, vii. 288.

SECTION X. *Of the Compounds of Zinc.*

1407. THE mode of ascertaining the composition of the oxide of zinc has been explained above, (767); it is only necessary to guard against the impurities of common zinc, which are chiefly iron, lead, and copper; the former is taken up by dilute sulphuric acid, and the two latter metals resist its action, and remain in the form of a black powder. Add to the sulphuric solution excess of ammonia, and apply a gentle heat; the oxide of iron will fall, and upon the addition of carbonate of potassa to the ammoniacal solution and boiling it, the pure oxide of zinc will be thrown down.

1408. The *oxide of zinc* of the *Pharmacopœia* is sometimes discoloured by a little iron; adulterated with chalk, or plaster of Paris; or contaminated by lead and arsenic. The presence of iron is shown by its solution in dilute nitric acid, neutralized by ammonia, becoming black with tincture of galls; chalk occasions an effervescence on adding the acid; gypsum is dissolved by boiling water, and detected by oxalate of ammonia and muriate of baryta. White arsenic is found by digesting in acetic acid, and adding solution of sulphuretted hydrogen, which occasions a yellow precipitate, in which arsenic is recognised by its smell when ignited on charcoal; and lead is shown by a black precipitate on adding sulphuretted hydrogen to the acetic solution.

1409. *Analysis of Chloride of Zinc.*—100 grains of chloride of zinc, obtained by heating the muriate in a glass tube to redness, and weighed while hot, to prevent error from deliquescence, were dissolved in water, and left 4 grains of oxide of zinc; accordingly 104 grains of the same chloride were dissolved, filtered, and decomposed by nitrate of silver, and the precipitate, washed, collected, and dried at a red heat, weighed 203 grains, equal to 50.4 of chlorine. The solution from which the chloride was precipitated contained nitrate of zinc, with a little nitrate of silver; muriate of ammonia was added to throw down the silver, in the state of chloride, which was separated upon a filter, and the clear liquor, evaporated to dryness, and ignited, afforded 62 grains of oxide of zinc, equivalent to 49.5 grains of metal; hence 100 grains of chloride of zinc gave

50.5	chlorine
49.5	zinc
100.	

1410. *Analysis of Sulphuret of Zinc.*—A specimen of yellow blende was analyzed as follows by Dr. Thomson.—*Annals of Philosophy*, iv. 94.

a. 50 grains, in fine powder, were digested for two days in dilute nitric acid; the whole was then thrown upon a filter, and the undissolved residue, washed and dried at 110°, weighed 26 grains.

b. These 26 grains were put upon a watch-glass and heated by a lamp; they burned like sulphur, and left a residue of 22.4 grains; the 3.6 grains of loss were considered as sulphur.

c. The 22.4 grains residue, which had now assumed the appearance of the original blende, were again digested for two days with dilute nitric acid: the second day, as all action was over, and the whole nearly dissolved, the flask was exposed for some hours to a heat of 130°; the whole was then thrown upon a filter, and the undissolved portion, washed and dried, weighed 0.54 grains.

d. This small residue was burned as before, by which it lost sulphur amounting to 0.16 grains, and 0.38 grains of residue remained.

e. This 0.38 grains had the appearance of small particles of quartz, and weighed 0.38 grains.

f. The two portions of acid liquid, which had been digested on the ore, and which contained the greatest part of it in solution, were mixed together, and almost, but not quite, saturated with carbonate of soda. A considerable excess of caustic ammonia was then poured in. By this alcali the oxide of iron was thrown down in yellowish-red flocks, while the whole of the zinc was held in solution. The oxide of iron being separated by the filter, washed, dried, and heated to redness, weighed 8.5 grains. Now this is equivalent to 5.98 grains of metallic iron.

g. The residual liquor was now boiled in a glass retort down to half its bulk, in order to drive off the ammonia, and precipitate the oxide of zinc. About one half of that oxide precipitates after a few minutes' boiling, but it requires considerable concentration before the other half falls down. From this circumstance it is not improbable that ammonia and oxide of zinc unite in two proportions.

The oxide of zinc thus obtained being washed, dried, and heated to redness, weighed 36.4 grains. This is equivalent to 29.32 grains of metallic zinc. It may be proper to mention that the oxide of zinc thus obtained was not quite white, but had a slight tinge of green. I conceived that this might be owing to the presence of copper, but if this metal was actually present, it was in too minute a quantity to be detected by the usual tests.

h. The liquid, thus freed from iron and zinc, was mixed with nitric acid, till it acquired a perceptibly sour taste. This was done to prevent any inaccuracy from the presence of ammonia, if any should still remain in the liquid. A solution of muriate of barytes was then mixed with it. The sulphate of barytes which precipitated, being washed, dried, and heated to redness, weighed 77.616 grains. Now 77.616 grains of sulphate of barytes contain 26.4 grains of sulphuric acid, or 10.56 grains of sulphur. From the preceding analysis it appears that blende is composed of the following ingredients :

Zinc	29.32	58.64
Sulphur	14.32	28.64
Iron	5.98	11.96
Quartz	0.38	0.76
	50.00	100.00

1411. I adopted the following process in the analysis of the crystallized *black blende* of Derbyshire :

a. 100 grains carefully separated from its siliceous matrix, were reduced to a fine powder, and dried at 600°. The loss of weight indicates water.

b. Upon the dried and powdered ore put into a Florence flask, I poured 2 ounces of nitro-muriatic acid, consisting of two of nitric and one of muriatic acid, in small successive portions, taking care to moderate the effervescence, and when this had subsided, a sulphureous magma floated upon the acid : the flask was placed in a sand heat, and with one additional ounce of nitro-muriatic acid, was digested until nearly the whole of the sulphur had disappeared, being converted into sulphuric acid. The whole contents of the flask were then poured into a conical glass, to allow a portion of undissolved matter to subside, which was separated by decantation, and proved to be silica, mixed with a little pure sulphur, the quantity of which was determined by burning it off, and ascertaining the loss of weight.

c. The decanted acid liquor was now evaporated considerably, so as to dissipate a portion of its excess of acid, and the residue divided into two equal portions, A and B. To A, considerably diluted with water, I added nitrate of baryta, and the precipitate being collected, washed, and dried at a red heat, was pure sulphate of baryta, and was used as the equivalent of the sulphur in the ore.

d. Carbonate of soda was added to the portion B, which threw down every thing, and the precipitate composed of the carbonate of zinc and peroxide of iron was digested in liquid ammonia, which took up the carbonate of zinc, leaving the oxide of iron undissolved.

e. The alcaline solution of zinc was decomposed by the addition of muriatic acid in slight excess, and to the acid muriate of potassa a little carbonate of soda was added to ensure the entire separation of the zinc; the zinc precipitate was now washed, dried, and ignited to reduce it to the state of pure oxide of zinc.

f. This ore contained neither copper nor arsenic, which are sometimes present in it.

1412. *Analysis of Calamine* (782).—Mr. SMITHSON (*Phil. Trans.*, 1803.) was the first to show that there are two distinct varieties of calamine; the one a true carbonate of zinc, and the other a compound of oxide of zinc and silica.

A specimen of crystallized calamine from Derbyshire afforded in the 100 parts

Silica	0.8
Oxide of iron	1.5
Oxide of zinc	65.0
Carbonic acid	32.7
	100.

The above ore was digested in dilute muriatic acid, in which it slowly dissolved with effervescence, with the exception of 0.8 grains of silica. The solution was evaporated to dryness, and the dry residue re-dissolved perfectly in water, leaving no further portion of silica. To this aqueous solution caustic ammonia was added in excess, so as to re-dissolve the oxide of zinc at first thrown down, and the whole thrown upon a filter, on which there remained 1.5 grains of oxide of iron. The ammoniacal solution was supersaturated by muriatic acid, and carbonate of ammonia was added to throw down the whole of the zinc, which precipitate, being dried and ignited, weighed 65 grains. The filtered solution was evaporated to dryness, and the residue being heated in a platinum capsule, entirely evaporated, and was merely muriate of ammonia. The loss therefore of 32.7 parts in the hundred may be regarded as carbonic acid.

1413. A specimen of *electric calamine* in small acicular crystals afforded, by digestion in nitric acid, a residue of 38.5 *per cent.* silica, which being separated by a filter, the filtrated liquor evaporated to dryness, and the dry mass, ignited for a quarter of an hour, gave 60 *per cent.* of oxide of zinc. The loss may be regarded as water, for the calamine lost upon ignition 2 *per cent.* in weight.

1414. *Assay of Zinc Ores.*—To ascertain the value of a sample of zinc ore, two methods may be resorted to. 1. Pick out the impurities and weigh off 1000 grains of the picked ore; give it a dull red heat in a muffle, taking care not to fuse it: mix the roasted ore with half its weight of lamp-black, put it into a small coated glass retort with its neck drawn to a very small aperture, and give it a red heat for one hour; cool it gradually, and the zinc will be found in drops in its neck. 2. Prepare and roast the ore as before, and stratify it in a crucible with its weight of clippings of sheet copper; lute a cover on the crucible, and give it a dull white heat for an hour. When cold, throw the contents into water, by which the brass may be separated from the other matter, and its increase of weight compared with the original copper gives the addition of zinc. In this process, however, a portion of zinc is always lost.

SECTION XI. *Of the Compounds of Tin.*

1415. THE *native oxide of Tin* (792) or *tin-stone*, in consequence of its mechanical aggregation, is almost insoluble in the acids, but it is rendered soluble by fusion with potassa, as Klaproth first remarked. (*Analytical Essays*, i. 522.) The following is the process given by that excellent analyst, and from the relative proportion of the tin to the oxygen, it appears that the metal exists in this ore in the state of peroxide.

a. 100 grains of tin-stone, from Cornwall, previously ground to a subtile powder, were mixed in a silver vessel with a lixivium containing 600 grains of caustic potash; this mixture was evaporated to dryness, and ignited for half an hour; when the mass thus obtained had been softened with boiling water, it left on the filter 11 grains of an undissolved residue.

b. These 11 grains again ignited with six times their weight of caustic potash, and dissolved in boiling water, left now only 1.25 grains of a fine yellowish-grey powder behind.

c. The alcaline solution (*a* and *b*) was saturated with muriatic acid, and oxide of tin was thrown down; this precipitate re-dissolved by an additional quantity of muriatic acid was precipitated afresh by means of carbonate of soda; when lixiviated and dried in a gentle heat, it acquired the form of bright yellowish transparent lumps.

d. This precipitate being finely powdered, entirely dissolved in muriatic acid, assisted by a gentle heat. Into the colourless solution, previously diluted with from two to three parts of water I put a stick of zinc, and the tin thus reduced gathered around it in delicate dendritic laminæ of a metallic lustre; these, when collected, washed, dried, and fused under a cover of tallow, in a capsule placed upon charcoal, yielded a button of pure tin weighing 77 grains.

e. The above-mentioned residue of 1.25 grains, left by the treatment with caustic potash (*b*), afforded with muriatic acid a yellowish solution, from which, by means of a little piece of zinc introduced into it, 0.5 grain of tin was still deposited; Prussian alcali added to the remainder of the solution, produced a small portion of a light blue precipitate, of which, after subtracting the oxide of tin now combined with it, hardly $\frac{3}{4}$ of a grain remained, to be put to the account of the iron contained in the tin-stone, here examined.

In these experiments (excepting only a slight indication of *silex* amounting to about $\frac{3}{4}$ of a grain), no trace has appeared, either of tungstic oxide, which some mineralogists have supposed to be one of the constituent parts of tin-stone, nor of any other fixed substance. Therefore, what is deficient in the sum, to make up the original weight of the fossil analyzed, must be ascribed to the loss of oxygen; and thus the constituent parts of this ore are to each other in the following proportion:

Tin	77.50
Iron	0.25
Silex	0.75
Oxygen	21.50
	100.

1416. Dr. Davy (*Phil. Trans.*, 1812.) in his analyses of the *Chlorides of Tin* (794, 795.) separated the metal by the immersion of a plate of zinc: from 67.5 grains of *chloride of tin* he thus procured 42. of metallic tin, whence inferring the proportion of chlorine from the loss of weight, he concludes that this chloride is composed of

62.22	tin
37.78	chlorine

In consequence of the volatility of the *perchloride of tin*, it is very difficult to weigh it with perfect accuracy; it was therefore poured into a bottle half-full of water, the weight of which was previously ascertained, and its quantity inferred by the increase of weight. The water was rendered slightly acid by muriatic acid, and 81.75 grains of the perchloride gave by the immersion of zinc 34 grains of tin: hence 100 of the perchloride may be regarded as consisting of

42.1	tin
57.9	chlorine

The quantity of chlorine in the chloride of tin cannot be ascertained by nitrate of silver, in consequence of the reduction of a portion of the silver; but having thrown down the zinc, the dissolved chloride of zinc may be decomposed by nitrate of silver, and thus the quantity of chlorine originally united to the tin may be ascertained.

1417. The following is Klaproth's analysis of the *Cupreous Sulphuret of Tin*, called *tin pyrites*, or *bell-metal ore*, from St. Agnes in Cornwall.

a. 120 grains of finely triturated tin-pyrites were treated with an aqua regia, composed of one ounce of muriatic and ½ ounce of nitric acid. Within twenty-four hours the greatest part of the metallic portion was dissolved without heat, while the sulphur floated on the surface; after the mixture had been digested for some time in a sand-heat, I diluted it with water, and filtered; it left 43 grains of sulphur, still mixed with metallic particles; when the sulphur had been gently burnt off on a test, there still remained 13 grains; of which eight were dissolved by nitro-muriatic acid: the remaining part was then ignited with a little wax; upon which the magnet attracted one grain of it. What remained was part of the siliceous matrix, and weighed three grains.

b. The solution of the metallic portion (*a*) was combined with carbonate of potash; and the dirty-green precipitate thus obtained was re-dissolved in muriatic acid diluted with three parts of water; into this fluid a cylinder of pure metallic tin weighing 217 grains was immersed; the result was that the portion of copper contained in the solution deposited itself on the cylinder of tin, at the same time that the fluid began to lose its green colour, from the bottom upwards, until, after the complete precipitation of the copper in the reguline state, it became quite colourless.

c. The copper thus obtained weighed 44 grains; by digestion in nitric acid it dissolved, and left one grain of tin behind in the character of a white oxide: thus the portion of pure copper consisted of 43 grains.

d. The cylinder of tin employed to precipitate the copper now weighed 128 grains, so that 89 grains of it had entered into the muriatic solution; from this, by means of a cylinder of zinc, I re-produced the whole of its dissolved tin, which was loosely deposited on the zinc in a tender dendritical form. Upon being assured that all the tin had been precipitated, I collected it carefully, lixiviated it cleanly, and suffered it to dry; it weighed 130 grains. I made it to melt into grains, having previously mixed it with tallow, under a cover of charcoal-dust, in a small crucible, which done, I separated the powder of the coal by elutriation; among the washed grains of tin, I observed some black particles of iron, which were attracted by the magnet, and weighed one grain; deducting this, there remain 129 grains for the weight of the tin; by subtracting again from these last those 89 grains, which proceeded from the cylinder of tin employed for the precipitation of the copper (*b*), there remained 40 grains for the portion of tin contained in the tin pyrites examined. Hence, including that one grain of tin which had been separated from the solution of the copper (*c*), the portion of pure tin contained in this ore amounts to 41 grains.

The *educts* or substances extracted in this process from tin pyrites were consequently

Sulphur	30 grains
Tin	41
Copper	43
Iron	2
Vein-stone or gangue	3
	119

Which makes, in a hundred parts,

Sulphur	25
Tin	34
Copper	36
Iron	2
	97

1418. *Assay of Tin Ores.*—If the ore contain arsenic, it should be powdered, mixed with a little charcoal, and roasted till vapours no longer rise. The residue mixed with a little pitch and sawdust, is to be put into a covered crucible, and exposed in a wind-furnace to a bright red heat for half an hour; when cool, break the crucible, and the button of metallic tin will be found at the bottom, which may be cleaned by gentle hammering and a wire brush, and weighed. The richest ores afford about 70 *per cent.* of metal.

SECTION XII. *Of the Compounds of Cadmium.*

1419. WE are as yet too little acquainted with the states of combination in which cadmium exists in its ores, and with the properties of the metal itself, to lay down precise rules for their analysis.

Mr. Stromeyer directs the digestion of the mixed oxide of zinc and cadmium in sulphuric acid, and passing through the acidulous solution a current of sulphuretted hydrogen gas: re-dissolve the precipitate in muriatic acid, evaporate to dryness, dissolve the residue in water, and precipitate by carbonate of ammonia, of which add excess to re-dissolve oxide of zinc, and of copper, should any be present; carbonate of cadmium remains.

According to Stromeyer, 100 parts of cadmium, when converted into oxide, absorb 14.35 of oxygen, and

$$14.35 : 100 :: 7.5 : 52.26$$

So that, upon this datum, the number 52.3 may be assumed as the equivalent of cadmium; a number widely different from that given above, 819, and 59.8 will be the representative of oxide of cadmium.

1420. The following are Stromeyer's analyses of the nitrate, sulphate, and carbonate of cadmium.—GILBERT'S *Annalen,* lx.:

Nitrate . .	100	nitric acid
	117.58	oxide of cadmium
Sulphate...	100	sulphuric acid
	161.1	oxide of cadmium
Carbonate	100	carbonic acid
	292.8	oxide of cadmium

Now, if we deduce the number for the oxide from these data, it will be about 60, which gives 52.5 as the equivalent of the metal.

Upon the same authority, the chloride, iodide, and sulphuret of cadmium may each be regarded as composed of one proportional of each of their components.

1421. The *Nitrate of Cadmium* is a white prismatic deliquescent salt composed of

1	proportional oxide	60.0
1	——— acid	50.5
4	——— water, 8.5 × 4 =	34.0
		144.5

1422. *Sulphate of Cadmium* forms large prismatic crystals, much resembling those of sulphate of zinc; very soluble and efflorescent, undergoing no change at a low red heat, but losing acid when heated to a bright red. It consists of

1	proportional	oxide	60.0
1	————	acid	37.5
4	————	water, 8.5 × 4 =	34.0
			131.5

1423. *Carbonate of Cadmium* is a white insoluble powder easily decomposed at a red heat. It consists of

1	proportional	oxide	60.0
1	————	acid	20.7
			80.7

SECTION XIII. *Of the Compounds of Copper.*

1424. THE method of determining the composition of the *Oxides of Copper* is described in paragraph 827.

1425. *Chloride of Copper* (829) was thus analyzed by Dr. Davy.—*Phil. Trans.*, 1812, p. 172:

a. 80 grains were dissolved in nitro-muriatic acid, and a plate of iron was immersed, upon which copper was precipitated, weighing, when well washed and perfectly dry, 51.2 grains.

b. The same quantity of the chloride, dissolved in nitric acid, and precipitated by nitrate of silver, afforded 117.5 grains of dry chloride of silver.

c. Since chloride of silver contains 24.5 *per cent.* of chlorine, 80 grains of chloride of copper must contain 51.2 grains of copper, (*a*) and 28.8 of chlorine, and 100 will consist of 36 chlorine + 64 copper.

The *Perchloride of Copper* may be analyzed exactly in the same way.

1426. The *Native Black Sulphuret of Copper* (844), or *Vitreous Copper Ore*, should consist in theory of

80	copper
20	sulphur
100	

In the following analysis of this ore by Klaproth (*Essays*, i. 542,) there is a close approach to these numbers; he probably lost a little sulphur by acidification, which might have been estimated by nitrate of baryta.

a. Upon 200 grains of the ore, coarsely powdered, moderately strong nitric acid was affused, which attacked and dissolved them with frothing and extrication of red vapours. The solution was clear, and the sulphur alone in the ore was left behind, floating in the fluid, in grey loose flocculi, without any other residue, which indicated that no antimony was present. The sulphur collected on the filter was heated in a small crucible to inflammation, and it burned with its peculiar odour, without any trace of arsenic; yet leaving a slight portion of oxided iron and siliceous earth.

b. The solution, which had a pure blue colour, was treated first with muriate and then with sulphate of soda, but these produced no alteration, by which it appears that this ore contains neither silver nor lead.

a. 200 grains of the powdered ore were heated with muriatic acid; as this alone manifested no action, I added nitric acid by drops, which exerted a strong attack. When the solution of the ore had been accomplished, I separated the fluid from the sulphur floating on the surface, and digested this last with a fresh quantity of muriatic acid, dropping into it some nitric acid; after which I collected it upon the filter. This sulphur, washed and desiccated, weighed 38½ grains, out of which after its combustion 1½ grain of siliceous earth remained; so that the true amount of sulphur was 37 grains.

b. The solution exhibits a glass-green colour. I divided it into two parts. Into one half polished iron was immersed, upon which the copper precipitated. It weighed 78½ grains when washed, and desiccated.

c. In order to ascertain the proportion of iron contained in the ore, I combined the other half of the solution with caustic ammoniac added to excess. The iron remained behind, in the form of brown oxide, which, collected on the filter, desiccated and ignited, weighed three grains. But as the iron is contained in the mixture of the ore in the reguline metallic state, these 3 grains give 2¼ of metallic iron to be added in the computation.

Therefore one hundred parts of the Siberian vitreous copper ore consist of

Copper, *b*.	78.50
Iron, c	2.25
Sulphur, *a*	18.50
Silex, *a*	0.75
	100.

The same method of analysis applies to the other sulphurets of copper or copper pyrites.

1427. The *Ferro-arsenical Sulphuret of Copper*, (844), was analyzed as follows by Mr. R. Phillips.—*Quarterly Journal of Science and Arts*, vii. 100.

a. Having ascertained that the constituents of this ore are copper, iron, arsenic, and sulphur, I boiled 100 grains of it reduced to powder in nitric acid, until the whole of the metallic matter appeared to be dissolved. 14 grains remained unacted upon by the acid; of these a large portion was evidently pure sulphur; by heat 9 grains were volatilized, and 5 remained, which were merely silica, that had been mechanically mixed with the ore.

b. The nitric solution was decomposed by potash, and being heated with excess of it, peroxide of copper and iron were precipitated together. This mixed precipitate was washed until it ceased to be alcaline, and was then dissolved in nitric acid. To the solution ammonia in excess was added; by this, peroxide of iron was precipitated, and the peroxide of copper held in solution; the former being separated, washed, and ignited, weighed 13.3 grains, equivalent to 9.26 of iron.

c. The ammoniacal solution of copper was heated, and when the greater part of the ammonia was expelled, potash was added to the solution; and, by continuing the heat, peroxide of copper was precipitated, which being washed and ignited, weighed 56.6 grains, equivalent to 45.32 of copper.

d. The alcaline solution obtained in *c*, and the water employed to wash the mixed precipitate of oxide of copper and iron, were evaporated together, and then saturated with nitric acid. This solution contained the sulphur and arsenic converted into acids, and combined with potash. Nitrate of barytes being added, sulphate was precipitated, which, being washed and ignited, weighed 126 grains, equal, according to Dr. Wollaston's scale, to 17.14 of sulphur, which, added to 9, before obtained, = 26.14. After this an accident happened to the solution, which prevented the separation of the arsenic acid; therefore,

e. 100 grains of the ore were again treated with nitric acid; with the silica 11 grains of sulphur were obtained, and the nitric solution was decomposed by excess of potash as before, in order to separate the oxide of copper and iron.

f. The alcaline solution being saturated with nitric acid, nitrate of barytes was added to it, as long as precipitation took place. The precipitated sulphate of barytes being washed and ignited, weighed 150 grains, = 20.4 sulphur, which, added to 11, separated without acidifying, = 31.4; the mean quantity of this and the first experiment being 28.74.

g. To the solution from which the sulphuric acid had been separated by nitrate of barytes, nitrate of lead was added as long as arseniate of lead was thrown down; and this, when washed and ignited, weighed 53 grains.

According to Dr. Thomson, 21.25 of arseniate of lead contain 7.5 of arsenic acid, equivalent to 4.75 of arsenic; if then, 21.25 give 4.75; 53 of arseniate of lead will indicate 11.84 of arsenic. It appears from these experiments, that this ore consists of nearly

Silica	5.
Iron	9.26
Copper	45.32
Sulphur	28.74
Arsenic	11.84
	100.16

In performing this analysis, some circumstances occurred which I think worthy of notice. In a preliminary experiment, I endeavoured to separate the copper from the iron by means of ammonia, without previously separating the arsenic acid; this I found impracticable, for it appeared that the arseniate of iron, at first precipitated, was eventually dissolved by the ammonia. In some treatises on chemistry, the arseniate of barytes is described as an insoluble salt: this, as may be deduced from what I have stated, is not the case. I first tried it by pouring a solution of arseniate of potash into one of nitrate of barytes; no precipitation occurred, but, upon standing some days, very delicate feathery crystals of arseniate of barytes were formed, which exhibited the prismatic colours with a splendour equal to that of the noble opal. I have since attempted, but without success, to reproduce the salt having this appearance*.

1428. *Native Phosphate of Copper* was analyzed by Klaproth nearly as follows: The ore was digested in nitric acid, by which it was entirely dissolved, with the exception of a remnant of silica. The nitric solution was divided into two parts; the phosphoric acid was precipitated from one, in the state of phosphate of lead, by adding acetate of lead; and from the weight of the phosphate of lead, the quantity of phosphoric

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* In paragraph 1031, it is stated, that when *neutral* arseniate of potassa is added to nitrate of baryta, an insoluble arseniate of baryta is thrown down, but if the binarseniate of potassa (1028) be used, the appearances are as above-described by Mr. Phillips, unless the solutions be very concentrated, in which case arseniate of baryta is presently thrown down.

acid was calculated. The other half of the solution was acted upon by iron to throw down the copper. He concluded from these experiments that the ore contained

68.13	oxide of copper
30.95	phosphoric acid
99.08	

It does not however seem clear whether the native phosphate of copper is a subphosphate of the peroxide, or a neutral phosphate of the protoxide; that is, whether it consists of 75 peroxide + 26 phosphoric acid; or of 67.5 protoxide + 26 phosphoric acid, these compounds requiring further investigation.

1429. *Native Carbonates of Copper.*—These, as well as the artificial carbonates have been analyzed by Mr. R. Phillips (*Quarterly Journal of Science and Arts*, iv. 274), and the results are given above, (857, *&c.*) The following is the process which he employed:

200 grains of green carbonate of copper heated to redness in a platinum crucible, became perfectly black, and lost 55.6 grains.

I put some nitric acid into a small phial, the stopper of which had been perforated, and a glass tube passed through it, to suffer the escape of the carbonic acid gas; the weight of the phial and acid being taken, I gradually put into it 200 grains of green carbonate of copper in small fragments. When the solution was complete, I found that 37 grains of carbonic acid had been evolved. If then from 200 we subtract 55.6, the loss by heat, we have 144.4 as the quantity of peroxide of copper; and if from 55.6 we take 37, the carbonic acid, there remain 18.6 as the proportion of water dissipated by heat. 100 parts of green carbonate of copper consist therefore of

Peroxide of copper	72.2
Carbonic acid	18.5
Water	9.3
	100.0

On examining the solution I found it to be pure nitrate of copper.

1430. The following comparative results will show how near in this instance experiment agrees with theory, if we regard the green carbonate of copper, or *malachite*, as consisting of 1 proportional of peroxide of copper, 1 of carbonic acid, and 1 of water; or as an hydrated subcarbonate.

	Vauquelin.	Phillips.	Theory.
Peroxide of copper	70.10	72.2	72.01
Carbonic acid	21.25	18.5	19.82
Water	8.65	9.3	8.17
	100.00	100.0	100.00

1431. *Assay of Copper Ores.*—When the ores contain sulphur and arsenic, they are roasted till fumes no longer arise, or reduced to powder and deflagrated with nitre. The residue is mixed with black flux (1012), and exposed for one hour to a bright red heat in a wind-furnace, when a button of copper is formed at the bottom of the crucible, the purity of which may be judged of by its appearance and malleability.

The oxides and carbonates of copper are reduced by simple fusion with black flux, care being taken to raise the heat sufficiently.

Section XIV. *Of the Combinations of Lead.*

1432. Lead constitutes a component part of several complex ores, the analyses of which are described in the sections on antimony and silver.

1433. *Galena* or *Sulphuret of Lead* (885) may be analyzed by the action of dilute nitric acid, which dissolves the lead and separates the sulphur: the lead may be precipitated by sulphate of soda: 100 grains of the sulphate of lead thus thrown down, after having been dried at a dull red heat, are equivalent to 69 of lead.

1434. Vauquelin analyzed a galena from Cologne, as follows. (*Journal des Mines*, No. 68.) It was heated with very dilute nitric acid; the undissolved residue, consisting of silica and sulphur, was heated to redness, by which the latter was dissipated, and pure silica remained. The nitric solution was decomposed by sulphate of soda, and the sulphate of lead collected, dried, and weighed, to estimate the proportion of metal. The remaining liquor being saturated by ammonia, gave a precipitate of oxide of iron; and lastly, carbonate of ammonia threw down carbonate of lime.

1435. A native *Sulphate of Lead* from Anglesea (889) was thus analyzed by Klaproth: 100 grains moderately heated lost 2 of water; the remainder was fused in a platinum crucible with four parts of carbonate of potassa, which gave a yellow hard mass partly soluble in water; the insoluble residue when dry was 72 grains of oxide of lead; it was dissolved in nitric acid, and this solution gave, when decomposed by the immersion of a rod of zinc, 66.8 grains of metallic lead. The alcaline solution from the crucible was saturated with nitric acid, and acetate of baryta added as long as it occasioned a precipitate, which weighed when quite dry 73 grains, equal to 25 of sulphuric acid. Hence it appears that this ore contains

66.5 lead	= 72	oxide of lead
5.5 oxygen		
	25	sulphuric acid
	97	
Loss, consisting of 1 gr. of oxide of iron, and 2 of water............	3	
	100.	

1436. *Native Phosphate of Lead* (896) was also examined by Klaproth; it is a distinctive character of this compound, that when fused into a globule before the blowpipe, it assumes, as it cools, a dodecaëdral form. 100 grains of green prismatic phosphate of lead dissolved entirely in nitric acid. Nitrate of silver gave a precipitate of 11 grains of chloride = 2.7 of chlorine. Sulphuric acid added to the warm solution gave 106 of sulphate of lead = 78.4 of oxide of lead: the liquor was then freed from excess of sulphuric acid by nitrate of baryta, and after having been nearly saturated by ammonia, acetate of lead was added; the phosphate of lead thus precipitated weighed 82 grains = 18.37 of phosphoric acid (more correctly 16.5). In the residuary solution was found a trace of iron.

1437. *Native Carbonate of Lead* (898) may be thus analyzed. Reduce the ore to powder and introduce 100 grains into a sufficient quantity of nitric acid diluted with about two parts of water; an effervescence ensues, and the carbonic acid may be estimated by loss of weight; it amounted to 16 grains. Filter the nitric solution, and if there be any insoluble residue, it is probably silica; to the filtered liquor add sulphate of soda, which throws down sulphate of lead, whence the oxide may be deduced; or immerse a plate of zinc into the nitric solution, which throws down metallic lead: in Klaproth's analysis he thus obtained 77 of metal equivalent to 82.5 oxide; whence it appears that the native carbonate contains

16.	carbonic acid
82.5	oxide of lead
98.5	

These numbers almost exactly agree with the theoretical composition of the carbonate of lead; the loss amounting to 1.5 may probably be considered as 0.5 carbonic acid and 1. water.

1438. The *Murio-Carbonate of Lead*, or *Native Muriate of Lead* (877), as it is generally called, was analyzed as follows, by Mr. Chenevix. (Nicholson's *Journal*, 4to. iv.) 100 grains, dissolved in nitric acid, lost 6 of carbonic acid; the nitric solution was neutralized by ammonia, and the absence of arsenic, phosphoric, and sulphuric acids proved by tests. Nitrate of silver was then added, which formed a copious precipitate, weighing when dry 48 grains, equivalent, according to Mr. Chenevix, to 8 of muriatic acid; he concludes that the 6 grains of carbonic acid saturated 34 of oxide of lead, and that 8 of muriatic acid saturated 51 of oxide of lead; and therefore that the ore consists of 59 muriate of lead and 40 carbonate of lead.

Klaproth's analysis agrees almost exactly with that of Mr. Chenevix, and they give the following view of the composition of this ore, but there is probably some considerable error in the estimate of the muriatic acid, and a new analysis is highly desirable.

Oxide of lead	85.5
Carbonic acid	6.
Muriatic acid	8.5
	100.0

1439. In the assay of lead ores by fire, a considerable loss is often sustained by the volatilization of the oxide of lead, and by its action upon the crucible, so that the operation is best performed by humid analysis; the ore may be digested in dilute nitric acid, and to the solution, when filtered, sulphate of soda may be added, which will throw down sulphate of lead; the latter, when washed and dried at a red heat contains about 68 *per cent.* of the metal.

SECTION XV. *Of the Combinations of Antimony.*

1440. THERE are three proper ores of antimony, *Native Antimony* (905), *Native Oxide of Antimony* (912), and the *Native Sulphuret* (905).

1441. Native antimony from Andreasberg was examined as follows by Klaproth (*Essays*, ii. 136.) 100 grains in powder were heated with nitric acid, the mixture diluted with water and filtered; muriatic acid, added to the filtered liquor, gave a precipitate of chloride = 1 grain of metallic silver; and the residual liquor gave oxide of iron = .25 gr. of metallic iron. The oxide of antimony upon the filter was perfectly soluble in muriatic acid; a piece of zinc, immersed in this muriatic solution, gave 98 grains of metallic antimony; hence the components are

Antimony	98.
Silver	1.
Iron	0.25
	99.25

1442. The *Native Oxide* or *white ore of Antimony* from Pritzbram, in Bohemia, was also analyzed by Klaproth; he found it a perfectly pure oxide, but did not ascertain the relative proportions of its component parts. According to Vauquelin, it contains silica and a little oxide of iron.—Hauy, iv. 274.

1443. The following is the analysis of an iridescent sulphuret of antimony, in acicular crystals, from Hungary.

a. 100 grains digested in two parts of nitric acid and one of water afforded a portion of sulphur, which, having been carefully separated from the adhering oxide, burned entirely away. It weighed 17.5 grains.

b. The insoluble oxide collected and washed, was re-dissolved in muriatic acid, and zinc immersed into the solution, by which 74 grains of metallic antimony were thrown down.

c. The nitric solution being evaporated to one-fourth, let fall a portion of white powder, which, treated as *b*, gave 2 grains of antimony.

d. The solution *c* appearing now to be free from antimony, was diluted and divided into two equal portions, A and B. Muriate of baryta, added to A, gave a precipitate of sulphate of baryta, weighing 22.5 grains, = about 3 grains of sulphur, or 6 in 100.

e. The portion B tested by muriate of soda gave no indication of silver; supersaturated with ammonia, it let fall 1.5 grains of peroxide of iron, to about 1 grain of iron.

f. The results of this analysis, therefore, are

Sulphur....	*a.* 20.5 grs. *d.* 6.	23.5 grs.
Antimony,..	*b.* 74. grs. *c.* 2.	76.0
Iron........	*e.*	2.
		101.5

The small increase of weight I refer to zinc adhering to the antimony.

1444. The *red ore of Antimony*, from Braunsdorff in Saxony, was analyzed by Klaproth; he digested it in muriatic acid, and threw down the antimony by water and potassa; the precipitate, after a second solution and precipitation, was re-dissolved in muriatic acid, and decomposed by a piece of polished iron, which caused the separation of 67.5 grains of metallic antimony. The sulphur he estimates at 19.70 *per cent.*, and attributes the loss of weight to oxygen combined with the antimony; he therefore regards the ore as a sulphuretted oxide of antimony, containing

Antimony	67.50
Oxygen	10.80
Sulphur	19.70
	98.

1445. The following is Mr. Hatchett's instructive analysis of *Bournonite*, or the *triple Sulphuret of Lead, Antimony*, and *Copper:*

A. 200 grains of the ore, reduced to a fine powder, were put into a glass matrass, and, two ounces of muriatic acid being added, the vessel was placed in a sand-bath. As this acid, even when heated, scarcely produced any effect, some nitric acid was gradually added, by drops, until a moderate effervescence began to appear.

The whole was then digested in a gentle heat, during one hour; and a green-coloured solution was formed whilst a quantity of sulphur floated on the surface, which was collected, and was again digested in another vessel, with half an ounce of muriatic acid.

The sulphur then appeared to be pure, and, being well washed and dried on bibulous paper, weighed 34 grains: it was afterwards burned in a porcelain cup, without leaving any other residuum than a slight dark stain.

B. The green solution, by cooling, had deposited a white saline sediment; but this disappeared upon the application of heat, and the addition of the muriatic acid in which the sulphur had been digested.

The solution was perfectly transparent, and of a yellowish green: it was made to boil, and in this state was added to three quarts of boiling distilled water, which immediately became like milk; this was poured on a very bibulous filter, so that the liquor passed through before it had time to cool; and the white precipitate thus collected, being well edulcorated with boiling water, and dried on a sand-bath, weighed 63 grains.

C. The washings were added to the filtrated liquor; and the whole was gradually evaporated at different times, between each of which it was suffered to cool, and remain undisturbed during several hours. A quantity of crystallized muriate of lead was thus obtained, until nearly the whole of the liquor was evaporated: to this last portion a few drops of sulphuric acid were added, and the evaporation was carried on to dryness; after which the residuum, being dissolved in boiling distilled water, left a small portion of sulphate of lead.

The crystallized muriate of lead was then dissolved in boiling water; and, being precipitated by sulphate of soda, was added to the former portion, was washed, dried on a sand-bath, and then weighed 120.20 grains.

D. The filtrated liquor was now of a pale bluish-green, which changed to deep blue, upon the addition of ammonia; some ochraceous flocculi were collected, and, when dry, were heated with wax in a porcelain crucible, by which they became completely attractable by the magnet, and weighed 2.40 grains.

E. The clear blue liquor was evaporated nearly to dryness; and, being boiled with strong lixivium of pure potash, until the whole was almost reduced to a dry mass, it was digested in boiling distilled water; and the black oxide of copper, being collected and washed on a filter, was completely dried, and weighed 32 grains.

200 grains of the ore, treated as here stated, afforded,

		Grains.
A.	Sulphur	34.
B.	Oxide of antimony	63.
C.	Sulphate of lead	120.20
D.	Iron	2.40
E.	Black oxide of copper	32.

But the metals composing this triple sulphuret are evidently in the metallic state; and white oxide of antimony precipitated from muriatic acid by water, is to metallic antimony as 130 to 100; therefore, the 63 grains of the oxide must be estimated at 48.46 grains of the metal.

Again, sulphate of lead is to metallic lead as 141 to 100; therefore, 120.20 grains of the former are = 85.24 grains of the latter. And, lastly, black oxide of copper contains 20 *per cent.* of oxygen; consequently, 32 grains of the black oxide are = 25.60 grains of metallic copper.

The proportions for 200 grains of the ore, will therefore be,

Sulphur	34.
Antimony	48.46
Lead	85.24
Iron	2.40
Copper	25.60
	195.70
Loss	4.30

SECTION XVI. *Of the Combinations of Bismuth.*

1446. THE principal ores of bismuth are, *Native Bismuth,* the *Sulphuret,* the *plumbo-cupriferous Sulphuret,* and the *Native Oxide.* Klaproth's analysis of the bismuthic silver ore will be found in a following Section.

1447. The *Sulphuret of Bismuth* has been analyzed by Sage (*Mém. de l'Acad. des Scien.*, 1782, p. 307.) but the following more complicated analysis of one of the ores of this metal renders it unnecessary to advert to other details.

1448. The *needle ore* of Siberia, or *Sulphuret of Lead, Copper, and Bismuth,* was examined as follows:

a. 50 grains, separated as far as possible from its quartzose matrix, were digested in nitric acid diluted with its bulk of water; when all action had ceased, a gentle heat was applied for a few hours, until no further action took place. The whole was then poured upon a filter, and the residue, being washed and dried, weighed 8.8 grains; it was burned, and there remained upon the capsule 2.3 grains of silica; the burned portion, amounting to 6.5 grains, being considered as sulphur. There was also an inappretiable portion of sulphate of lead.

b. The filtered solution being evaporated, let fall crystals of nitrate of lead; the evaporation was carried nearly to dryness, and the residue, put into 8 ounces of water, deposited a quantity of oxide of bismuth, which being collected, washed, and dried, weighed 20 grains.

On evaporating the filtered liquor to half its bulk, there was a further deposit of 3 grains of oxide of bismuth. Now, 23 grains of oxide of bismuth may be computed as equal to 20.5 of the metal.

c. The evaporation was now carried nearly to dryness, a portion of excess of acid driven off, and the residue again diluted, by which a very slight turbidness was produced, but no appretiable portion of bismuthic oxide deposited. I therefore poured sulphate of soda into the solution, and the precipitate of sulphate of lead thus formed, weighed, when dry, 18.5 grains, equivalent to about 12.7 of lead.

d. The filtered liquor was now evaporated to dryness, and the residue dissolved in a small quantity of water; carbonate of soda was added, and the blue precipitate being collected and washed, was digested in ammonia, in which it was totally soluble; the ammonia being driven off, the residue was heated red-hot, and had the properties of pure peroxide of copper; it weighed 8 grains, which is nearly equivalent to 6.5 of copper.

These were all the components of this triple sulphuret which I could separate, though, from its odour before the blowpipe, I suspect the existence of a trace of arsenic in it: the following, therefore, are the results of the analysis:—

Sulphur (*a*)	6.5	grains
Bismuth (*b*)	20.5	
Lead (*c*)	12.7	
Copper (*d*)	6.5	
	46.2	
Silica (*a*)	2.3	
Loss	1.5	
	50.0	

From the small quantity of the needle ore in my possession, I could not repeat this analysis, nor could I employ separate portions for the separation of its several components.

Dr. John (*Chemische Untersuchungen*, p. 216.) whose analysis is, I believe, the only one previously published, gives the following as the composition of this ore of bismuth:

Bismuth	43.20	21.60
Lead	24.32	12.16
Copper	12.10	6.05
Sulphur	11.58	5.79
Nickel	1.58	0.79
Tellurium?	1.32	0.66
Gold	0.79	0.39
	94.89	47.44
Loss	5.11	2.56
	100	50.00

It may be observed, that in both these analyses, but especially in the latter, the proportion of sulphur falls short of that required to constitute the respective sulphurets of lead, copper, and bismuth, and that the loss therefore may be most plausibly ascribed to sulphur.

1449. The *Native Oxide of Bismuth* consists, according to Lampadius, of

Oxide of bismuth	86.3
Oxide of iron	5.2
Carbonic acid	4.1
Water	3.4

Heat would expel both the water and carbonic acid from this compound: the relative proportion of the latter might be learned by the loss of weight during effervescence. The ore might then be dissolved in the smallest possible quantity of nitric acid, and excess of ammonia would precipitate the peroxide of iron, but retain the bismuth in solution; the oxide of bismuth might then be obtained by evaporation to dryness, and exposure to heat sufficient to decompose the nitrate of ammonia.

SECTION XVII. *Of the Combinations of Cobalt.*

1450. THE analyses of the chloride and of the sulphate of cobalt are given in Section XVII. of the preceding Chapter, (paragraphs 960 and 969.) from which the equivalent of the metal is deduced.

The principal difficulties that occur in examining the combinations of cobalt are, its separation from arsenic, from nickel, and from copper, which may be performed as follows.

a. 100 grains of an alloy of cobalt, arsenic, nickel, and copper, are digested in nitric acid till perfectly dissolved; the solution is then evaporated to dryness, and a fresh portion of nitric acid distilled off the dry salt, in order to ensure the complete acidification of the arsenic; the residue, consisting of arseniates of cobalt, copper, and nickel, may then be treated by nitrate of lead, which will remove the arsenic acid in the form of insoluble arseniate of lead; but a more convenient method of proceeding is perhaps as follows: boil the arseniates repeatedly in solution of potassa, until that alcali no longer takes up arsenic acid; the oxides of cobalt, nickel, and copper, will thus be obtained nearly, if not quite, free from arsenic acid.

b. To separate the oxides of copper, cobalt, and nickel, dissolve them (in the state of hydrates) in dilute nitric acid, and immerse a plate of iron, which will throw down metallic copper, and a mixed nitrate of iron, cobalt, and nickel, will be obtained.

c. To this mixed nitrate add potassa, wash the precipitate, and digest it in ammonia, which will take up the oxides of cobalt and nickel, leaving the peroxide of iron.

d. The ammoniated solution of cobalt and nickel may be treated as directed by Mr. R. Phillips, (*Phil. Magazine,* xvi. 313.) Evaporate it till the excess of ammonia is expelled (which is known by no change of colour being produced by it on turmeric paper), and then add solution of potassa, and dilute considerably; the oxide of nickel instantly falls, but that of cobalt remains some time in solution, and may be obtained by neutralizing the alcaline liquor.

1451. The following is Tassaert's analysis of the *Arsenical Cobalt,* or *white cobalt glance* of Tunneberg.

That the reader may better understand the process, it may be premised, that when reguline arsenic is boiled with a *little* nitric acid, it is dissolved and converted into white oxide, all of which is deposited by mere evaporation to a small bulk of liquid; but when *much* nitric acid is used, the arsenic is more or less acidified, becomes thereby much more soluble in water, and then acting as an acid, it readily dissolves cobalt, iron, *&c.*, forming arseniates of those metals, which are decomposable by the fixed alcalis. It may be also added, that oxide of cobalt is soluble in ammonia, but oxide of iron is not; and that the nitrate of iron deposits much of its iron by mere exposure to air, but the nitrate of cobalt remains clear.

A. To estimate the quantity of arsenic separately, M. Tassaert digested 100 parts of the cobalt ore with dilute nitric acid, and in some hours the whole was dissolved, but by cooling deposited a quantity of white crystalline grains. On evaporation, more of them were deposited, and when all had thus separated, they were collected and dried, and weighed 56 parts, all of which was sublimed by heat except 3 parts, probably a mixture of arsenic and cobalt. Hence the oxide of arsenic from this ore may be reckoned at about 53 parts, indicating 49 *per cent.* of metallic arsenic in the ore.

B. 300 parts of the ore were then digested with four times as much nitric acid, which made a rose-coloured solution. By partial evaporation, adding water, and heating, a rose-white precipitate (*a*) fell down, leaving a rose-coloured solution. This solution, boiled with an excess of potash, gave an oxide of cobalt, at first rose-coloured, then passing to green, and, when dried in a red heat, black. It weighed 85 parts.

C. The 85 parts of the last experiment were then examined for iron. When re-dissolved in nitro-muriatic acid, pure ammonia was added, which gave a black precipitate, which was all re-dissolved by an excess of the alcali except a small portion, which, again treated with nitro-muriatic acid and ammonia, was reduced to 4 parts, and appeared to be oxide of iron.

D. The rose-precipitate of experiment B, which proved to be a mixed arseniate of cobalt and iron, was decomposed by caustic potash in excess, and gave a precipitate weighing 100 parts when dried.

E. The 100 parts of the last experiment were re-dissolved in nitric acid, the solution evaporated partly, and then diluted with water; a precipitate of oxide of iron weighing 27 parts then separated, and a clear solution of cobalt was left.

F. The nitrate of cobalt of the last experiment was decomposed by ammonia, and the precipitate re-dissolved by an excess of the alcali, except 1.5 parts of insoluble oxide of iron: the solution was added to the ammoniated cobalt of experiment C.

G. The insoluble precipitates of oxide of iron of C, E, and F, were then mixed and examined: they still gave a blue glass with borax, and therefore contained a certain portion of cobalt. Acetic acid was found a good method of separating them: for this purpose they were re-dissolved in nitro-muriatic acid, precipitated by just sufficient ammonia, and the precipitate whilst still wet was put into acetic acid. This dissolved the whole at first, but on boiling and evaporating the solution nearly to dryness, most of the iron separated, and by re-dissolving in water and evaporating nearly to dryness successively four times, nearly all the oxide of iron was rendered insoluble, whilst the cobalt remained in the solution, and this acetited cobalt in proportion as it was freed from iron became more and more of a fine rose colour. This last was then supersaturated with ammonia, and the solution of ammoniated cobalt was added to the different portions of the same obtained in the former experiments. The whole was then boiled to expel the excess of ammonia, and by adding potash the whole of the pure oxide was precipitated, which, when well washed and dried, weighed 133 parts. This oxide reduced in a crucible lined with charcoal, gave regulus of cobalt in its purest form, of the specific gravity of 8.538, and to all appearance totally free from arsenic and iron.

II. Lastly, to estimate the quantity of sulphur, 100 parts of the ore were separately boiled with 500 of nitric acid, and diluted with water, to separate all the oxide of arsenic that would be deposited spontaneously. All the sulphur being now converted into sulphuric acid by the action of the nitric acid, nitrate of barytes was added, and from the precipitated sulphate of barytes, the quantity of sulphuric acid, and of course, of sulphur, was estimated according to known proportions. —AIKIN'S *Dictionary*, i. 307.

SECTION XVIII. *Of the Combinations of Uranium.*

1452. IN Section XVIII. of the preceding Chapter the *Pechblende* of mineralogists is erroneously represented as a *Native Sulphuret of Uranium;* it is, however, an oxide of uranium, combined with a little oxide of iron, sulphuret of lead, and silica; probably accidental ingredients, as shown by the following results of Klaproth's analysis of the *pitch ore of uranium*, from Joachimsthal:

Oxide of uranium	86.5
Oxide of iron	2.5
Sulphuret of lead..........	6.0
Silica	5.0
	100.

1453. The following is a general process for the analysis of uranitic ores.

a. Digest in dilute nitric acid, which separates sulphur and silica (if sufficiently dilute without the acidification of the former); burn off the sulphur, and the silica remains.

b. To the nitric solution add sulphate of soda, which separates lead in the state of sulphate.

c. To the remaining solution add liquid potassa in excess, and boil; filter, wash the precipitate, and digest it in pure ammonia, which takes up the copper, and which may be obtained by immersing a plate of zinc in the ammoniacal solution slightly supersaturated with sulphuric acid.

d. Digest the portion of the precipitate *c*, insoluble in ammonia, in bi-carbonate of potassa, which, if used in sufficient quantity, takes up oxide of uranium, leaving oxide of iron.

1454. The *Micaceous Uranite*, from the Gunnis Lake mine in Cornwall, was analyzed as follows, by Mr. Gregor (*Annals of Philosophy*, v. 281.):

a. 100 grains lost, by exposure to a low red heat, 15.4 grains of water.

b. 100 grains (not previously ignited), repeatedly boiled in excess of nitric acid, left a residue amounting only to 0.1 grain of silica and oxide of iron.

c. Excess of ammonia added to the nitric solution, threw down a yellow precipitate, which, digested in excess of ammonia, gave a blue solution, and left 74.9 grains of oxide of uranium, not quite pure.

d. The ammoniacal solutions were evaporated to dryness, and the residue again digested in ammonia left 0.2 grains of oxide of uranium. The ammoniacal solution again evaporated, and the residue dissolved in nitric acid, gave with potassa a precipitate, which dried and ignited, was 7.65 grains of oxide of copper.

e. The 74.9 grains of oxide *c*, digested in dilute sulphuric acid, left a trace of lead. The sulphuric solution, precipitated by excess of ammonia, still showed traces of copper, and by a cylinder of zinc gave 0.5 grains of metallic copper = 0.62 of oxide; so that the 74.9 grains of process *c* were reduced to 74.28, to which add the 0.2 grains of process *d*, and it gives the whole amount of oxide of uranium = 74.48. The results of the above analysis are

Oxide of uranium, with a trace of lead........	74.48
Oxide of copper, *d e*	8.20
Water	15.40
	98.08
Loss	1.92
	100.00

SECTION XIX. *Of the Combinations of Titanium.*

1455. KLAPROTH and Vauquelin have furnished analyses of the titanitic ores, of which the following examples will suffice.

The *silico-calcareous titanite* from Bavaria was thus analyzed by Klaproth (*Essays*, i. 214.):

a. 100 grains in fine powder were ignited for an hour with 400 grains of caustic potassa, and the resulting mass digested in muriatic acid left 12 grains of silica.

b. Carbonate of potassa was added to the muriatic solution, and the precipitate thus obtained, being again digested in muriatic acid, left 23 grains of silica.

c. Caustic ammonia was then added to the preceding solution, and the precipitate dried and ignited gave 33 grains of oxide of titanium.

d. To the remaining fluid, whilst boiling, carbonate of potassa was added, and the precipitate having been duly ignited, gave 33 grains of lime.

The following then are the component parts of this mineral:

Silica, *a b*	35 grains
Oxide of titanium, *c*	33
Lime, *d*	33
	101

1456. The following is Vauquelin's analysis of the *Menachanite* of Bavaria (*Journal des Mines*, No. 19.):

a. 100 grains finely pulverized were fused for an hour and a half in a silver crucible, with 400 grains of potassa; the fused mass, digested in water, left 124 grains of red insoluble powder.

b. The 124 grains were boiled with potassa, and the solution, after saturation with muriatic acid, was treated with carbonate of potassa, which threw down 3 grains of oxide of titanium.

c. The residue of the 124 grains was digested with dilute muriatic acid, which left 46 grains of oxide of titanium.

d. The muriatic solution, saturated by ammonia, gave 50 grains of oxide of iron.

e. The alcaline solution *a*, which was of a green colour, was supersaturated by muriatic acid, and evaporated to dryness; the dry residue contained no silica, for it dissolved entirely in water; on the addition of carbonate of potassa, it yielded 2 grains of carbonate of manganese.

SECTION XX. *Of the Combinations of Cerium.*

1457. *Cerite* (997) was analyzed, with the following results, by Vauquelin (*Annales du Muséum*, v. 412.):

67	oxide of cerium
17	silica
2	oxide of iron
2	lime
12	water and carbonic acid
100	

The following directions for the analysis of this ore are given by Messrs. Aikin:

a. Having minutely pulverized the ore, weigh it, then ignite it and weigh it again; the difference may be set down as the amount of water.

b. Digest the calcined ore in repeated portions of nitro-muriatic acid, and when nothing further is taken up, fuse the residue with caustic potash; then dissolve out the mass by muriatic acid, evaporate to dryness, and digest again in very dilute muriatic acid; the insoluble residue is silex.

c. Add together the muriatic and nitro-muriatic solutions, and decompose the whole at a boiling heat by saturated carbonate of potash; re-dissolve the whole in as little muriatic acid as possible, heat the solution to drive off the last remains of carbonic acid, and add perfectly caustic ammonia till there is an evident excess; separate the precipitate, and add to the clear liquor as much muriatic acid as will saturate it, and then throw down from it the lime in the state of carbonate, by means of a mild alcali.

d. The ammoniacal precipitate, consisting of the oxides of cerium and iron, is to be dissolved in muriatic acid, and liquid hydrosulphuret of potash is to be dropped in till the precipitate, which at first will be greenish, becomes white; the clear liquor being separated and treated with carbonate of potash, affords a white precipitate, which is carbonate of cerium.

e. The greenish precipitate is to be dissolved in as little muriatic acid as possible, and the solution being neutralized by an alcali to the point of precipitation, sulphate of soda is to be added, which will throw down a sulphate of cerium; the residual fluid being then decomposed by ammonia, deposits oxide of iron.

f. The sulphate of cerium *e* is now to be boiled with thrice its weight of carbonated soda, by which it will be converted into carbonate, which is to be dissolved in dilute muriatic acid, and again precipitated by carbonate of potash or of soda.

g. The carbonates of cerium (*d* and *f*) are now to be calcined, by which the pure brown oxide of cerium will be obtained.—*Addenda to the Dictionary*, iii. 509.

1458. *Allanite*, (997) analyzed by Dr. Thomson (*Edinburgh Phil. Trans.*, vi. 385.) was found to contain the following substances:

Oxide of cerium	33.9
Oxide of iron	25.4
Silica	35.4
Lime	9.2
Alumina	4.1
Water	4.0
	112.0

SECTION XXI. *Of the Combinations of Tellurium.*

1459. THE following is an outline of the analysis of several compounds of tellurium given by Klaproth, in his *Chemical Examination of the Auriferous Ores of Transylvania*, ESSAYS ii. 1.

1460. *Native Tellurium,* from Fatzebay in Transylvania, contains, according to that celebrated analyst,

92.55	tellurium
7.20	iron
0.25	gold
100.	

The following method was pursued in the decomposition of this ore:

a. It was separated as much as possible from its stony matrix and pulverized, was digested in six parts of warm muriatic acid, to which were added, cautiously and at intervals, three parts of nitric acid: the compound acid acted violently on the ore, and took up the whole of it except the quartzose matrix.

b. The acid solution being diluted with as much water as it would bear without decomposition, was combined with caustic potassa, upon which a copious precipitate fell down; more alcali was then added, till the whole of the precipitate that was resoluble in this menstruum was taken up. There remained behind a dark-brown residue, consisting of the oxides of gold and iron.

c. The residue of *b* was then dissolved in nitromuriatic acid, to which was afterwards added, drop by drop, nitrate of mercury, prepared in the cold, as long as the precipitate thus formed appeared of a brown colour; this precipitate, consisting of gold and muriate of mercury, was then pretty strongly ignited in a crucible with borax, by which the mercury was driven off, and a button of pure gold remained.

d. To the nitro-muriatic solution *c*, was now added caustic alcali, by which the oxide of iron was thrown down.

e. The alcaline solution *b* was accurately saturated with muriatic acid, and then heated, by which a white heavy powder was obtained; which, after being washed in a mixture of equal parts of alcohol and water, and then gently dried, was pure oxide of tellurium.

1461. The *grey ore of Tellurium*, or *Graphic Gold*, of Offenbanya, contains

60	tellurium
30	gold
10	silver.

This ore was treated in the following manner:

a. The finely pulverized ore was digested in nitro-muriatic acid till nothing more was taken up.

b. The insoluble residue, consisting of quartz and muriate of silver, was fused with five times its weight of carbonated soda, by which the silver was obtained in the metallic state.

c. The nitro-muriatic solution being concentrated by evaporation, was largely diluted by alcohol, upon which the oxide of tellurium precipitated; and this being redissolved in muriatic acid, was obtained in black metallic flocculi, by means of a bar of polished iron.

d. The nitro-muriatic solution *c*, after separation of the tellurium, contained only gold, which was procured by the addition of a solution of green sulphate of iron.

1462. The *yellow ore of Tellurium*, from Nagayag, is composed, according to Klaproth, of

44.75	tellurium
26.75	gold
19.50	lead
8.50	silver
0.50	sulphur
100.	

He performed the analysis of this ore nearly as follows:

a. 400 grains of the pulverized ore were digested with nitric acid, till every thing soluble in this fluid had been taken up.

b. The nitrous solution was combined with muriatic acid, as long as any precipitation took place; by this there was obtained 51 grains of a white powder, of which 43 grains were again resoluble in boiling water. The insoluble portion, amounting to 8 grains, was muriated silver.

c. The solution, containing the 43 grains above-mentioned, was concentrated by gradual evaporation, and afforded delicate needle-form-crystals of muriated lead.

d. The residue of *a*, insoluble in nitric acid, was then treated with nitro-muriatic acid, as long as any thing was taken up; the solution was mixed with the nitro-muriatic solution *b*, and reduced by evaporation till it ceased to deposit muriate of lead. 11 grains were thus obtained.

e. To the concentrated solution *d*, was added caustic potash in excess, which threw down a copious blackish-brown precipitate; this being separated, the alcaline liquor was saturated with muriatic acid, and the white precipitate thus obtained, being again dissolved in muriatic acid, and then precipitated by means of a stick of zinc, afforded 85 grains of metallic tellurium.

f. The blackish-brown precipitate of *e* was dissolved in nitro-muriatic acid, and the liquor was nearly saturated with caustic potash; nitrated mercury was then added, till the precipitate began to be white; this precipitate being separated by the filter, and washed, the filter, with its contents, was ignited in a crucible, and a little nitre being added, the fire was increased, and a button of pure gold was thus obtained, weighing 50.75 grains.

g. The remainder of the nitro-muriatic solution *f* was saturated with carbonated potash, and a precipitate was obtained, consisting of oxide of manganese, mixed with carbonated lime, and a little alumine and oxide of iron.

h. The insoluble residue of *d*, weighing 120.5 grains, and consisting chiefly of quartz, was gently heated, by which it lost about 1 grain, which was sulphur; being then mixed with four times its weight of carbonated potash, and fused, there was obtained a button of silver, weighing 10.125 grains.

1463. The *black ore of Tellurium*, also from Nagayag, according to the same analyst consists of

54.0	lead
39.2	tellurium
9.0	gold
0.5	silver
1.3	copper
3.0	sulphur
100.0	

This ore was analyzed in the following manner:

a. 1000 grains of the pulverized ore were digested with 10 ounces of muriatic acid, to which was added, by degrees, a little nitric acid: this being poured off, 5 ounces more of muriatic acid were added, by which every thing soluble in this menstruum was taken up; to the filtered solution boiling water was added, to re-dissolve the muriate of lead which had begun to be deposited.

b. Of the insoluble residue a part had cohered into a mass, and was for the most part sulphur, weighing 17.5 grains; being gently ignited, it left behind 3.5 grains of a blackish matter, which was dissolved in muriatic acid, and added to the foregoing solution. Hence the sulphur of the ore amounted to 14 grains.

c. The remainder of the insoluble residue was for the most part quartz, and weighed 440.5 grains. Being melted with four times its weight of carbonated potash, there appeared, on breaking the mass, a few globules of silver, amounting to about 2.5 grains, equivalent to 3.5 grains of muriated silver; so that the quartzose matrix was equal to 437 grains.

d. The solution *a* being concentrated by evaporation, crystals of muriated lead were deposited, to the amount of 330 grains, equivalent to 248 of metallic lead.

e. Having thus separated the lead, the remainder of the solution was largely diluted with alcohol, by which a white oxide of tellurium was thrown down; this oxide being re-dissolved by muriatic acid, and again precipitated by caustic soda, afforded 178 grains of oxide, equivalent to 148 grains of reguline tellurium.

f. The alcoholic solution was next distilled, by which the alcohol was separated; the residual fluid being diluted with water, was treated with nitrate of mercury, in the way already described, by which a button of gold weighing 41.5 grains was obtained.

g. The residual fluid of *f* was saturated with carbonated soda, and boiled, by which a bluish-grey precipitate was obtained; by digestion in muriatic acid it dissolved, and oxy-muriatic acid gas was produced; the muriatic solution being then supersaturated with carbonated ammonia, there was deposited carbonated manganese, mixed with iron, to the amount of 92 grains.

h. The ammoniacal solution was of a blue colour, upon which it was supersaturated with sulphuric acid, and a plate of iron being immersed in the fluid, there were deposited 6 grains of copper.

The above abridged account of Klaproth's analyses of the ores of tellurium is extracted from Messrs. AIKIN's *Dictionary*, and contains a variety of instructive details to the student in analytical chemistry.

SECTION XXII. *Of the Combinations of Selenium.*

1464. THE compounds of this substance have hitherto been examined by Berzelius only; he discovered it, as has already been stated, in the sulphuret of iron from Fahlun, from which sulphur is obtained for the formation of sulphuric acid; when burned for this purpose, a brown compound remains, which consists of sulphur, and a peculiar substance exhaling a strong smell of horse-radish when heated by the blowpipe: this substance, called by its discoverer *Selenium* (from σεληνη, the moon), indicative of its analogy to *Tellurium,* was separated in minute portions from the brown compound by a very tedious analysis, of which the essential part consisted in digesting it to dryness in nitro-muriatic acid, adding water, and filtering; excess of muriate of ammonia, added to the filtered liquid, threw down selenium.

In this state selenium fuses a little above 212°, assuming, when cool, a brown colour, metallic lustre, and crystalline texture.

It combines with two proportions of oxygen, forming an oxide and an acid; the acid consists of 100 selenium + 38 oxygen; if, therefore, we regard it as containing 1 proportional of selenium + 2 of oxygen, the number 39.4 will represent selenium, and 54.4 selenic acid. But, according to Berzelius's analyses of the *Seleniate of Baryta,* it is composed of

Selenic acid	100.0
Baryta	137.7

and these numbers give 52.6 as the equivalent of the acid.

1465. Selenium combines with chlorine, forming a volatile yellow compound: its action upon iodine has not been examined. Combined with potassium, and acted on by dilute muriatic acid, a colourless gas is disengaged, somewhat resembling sulphuretted hydrogen in its odour, and extremely irritating: it is soluble in water, reddens vegetable blues, and causes precipitates in metallic solutions. This gas, which is a true *seleniuretted hydrogen,* consists of 1 proportional of selenium + 1 of hydrogen.

1466. *Sulphuret of Selenium* is an orange-coloured compound, formed by passing sulphuretted hydrogen gas through a solution of selenic acid in water. It appears to be a *sesqui-sulphuret,* containing 3 proportionals of sulphur + 2 of selenium.

1467. *Phosphuret of Selenium* is a fusible brown compound, which has not been analyzed.—Berzelius. *Annales de Chemie et Physique,* ix. *Annals of Philosophy,* xiii. Thomson's *System,* 6th Edit., i. 297.

1468. The following analysis of a supposed ore of tellurium, from Sweden, by Berzelius, and in which he discovered selenium, I subjoin as an example of his method of proceeding (Children's *Translation of* Thenard *on Analysis,* 408.):

a. 100 parts of the purest portions of the mineral, carefully selected, were dissolved in boiling nitric acid, the solution diluted with boiling water, and filtered; the clear liquor gave a precipitate with solution of common salt, and the matter which remained on the filter was washed with boiling diluted nitric acid, as long as the washings were rendered turbid by solution of sea-salt.

The chloride of silver, after being washed, dried, and fused, weighed 50.7 parts, equal to 38.93 of silver. The substance remaining on the filter consisted of silica and stony matter, and weighed, after being heated, 4 parts.

b. The liquid from which the silver had been separated was precipitated by sulphuretted hydrogen gas; the precipitate re-dissolved in aqua regia, and the solution concentrated till the nitric acid was entirely decomposed. It was then diluted with water, and sulphite of ammonia added, when the liquid gradually became turbid, and acquired a cinnabar red colour. After some hours it was boiled, and small portions of sulphite of ammonia added from time to time. The boiling was continued two hours, in order to precipitate the whole of the selenium; collected, dried, and heated nearly to fusion on the filter, it weighed 26 parts.

c. From the liquid, separated from the selenium, and deprived of its sulphurous acid by boiling, subcarbonate of potassa threw down a green precipitate, which, when washed, dried, and heated red, was converted into black oxide of copper, and weighed 27 parts, equivalent to 21.55 of copper. This oxide, dissolved in muriatic acid, gave a blue solution, with an excess of ammonia. The alcaline liquor, from which the carbonate of copper had been separated, still retained a greenish tinge; it was concentrated and slightly acidulated with muriatic acid, and a further precipitate of 1.5 part of copper separated by a plate of iron, which makes the whole of the copper 23.05.

d. The liquid, precipitated by sulphuretted hydrogen, (*b*) was deprived of the excess of gas by boiling, and mixed with caustic ammonia, which threw down a yellowish precipitate, weighing, when dried, 1.8 parts, and was a mixture of oxide of iron with a little alumina. The remaining solution was mixed with subcarbonate of potassa in excess, and evaporated to dryness. The saline mass, re-dissolved in water, left a white earth, which, heated red, weighed 3.4 parts. Sulphuric acid, mixed with this earth, occasioned an effervescence, and by evaporation became gelatinous, and deposited silica;

it appeared also to contain magnesia, but it was not particularly examined, as these earths were evidently foreign to the ore.

The results of the analysis then are,

Silver	38.93
Copper	23.05
Selenium	26.00
Earthy and foreign substances	8.90
Loss	3.12
	100.00

The loss must be partly attributed to the carbonic acid of the carbonate of lime; still more to selenium, which it is difficult to separate entirely; and partly to the loss unavoidable in this sort of experiments.

SECTION XXIII.—*Of the Combinations of Arsenic.*

1469. THE method of separating arsenic from some of its combinations, and estimating its quantity has already been adverted to; some further account of the process, and of the analysis of arsenical combinations remains to be given in this section.

Where the object is merely to drive off the arsenic contained in any ore, it may be effected by reducing it to powder, mixing it with saw-dust, or charcoal, and applying a dull red heat for some hours; the carbonaceous material, by keeping the arsenic in the metallic state facilitates its escape in the form of vapour, and by dividing the material, prevents its running into lumps by partial fusion.

1470. To estimate the quantity of iron in the *arsenical pyrites,* Messrs. Aikins advise the following as a short and convenient process: "Add to the powdered ore dilute nitric acid, and digest in a gentle heat; this will dissolve all the arsenic and iron, whilst most of the sulphur, with the siliceous residue, will remain undissolved. Pour off the nitrated solution, mix with it about twice as much powdered charcoal as the quantity of ore employed, and evaporate nearly to dryness; put the residue into a tall crucible, and apply a brisk red heat for about ten minutes, by which time the arsenic will be almost entirely driven off in copious fumes, and the residue will consist of little else than charcoal and oxide of iron. Spread this upon a heated tile, till the charcoal is almost burned off by which any arsenic still adhering will be dissipated, and the remaining oxide of iron may be reduced, or estimated as mentioned under that metal. The nitrous acid is preferable to the muriatic in this process, as the latter, when strongly heated, volatilizes part of the iron, and renders the assay incorrect."—*Dictionary*, i. 95.

1471. In the analysis of ores containing arsenic, the most certain method of estimating its quantity, consists in acidifying it by nitric acid; the arsenic acid may then be thrown down, with due precautions, by nitrate of lead, and the proportion of arsenic deduced from that of the arseniate of lead; the following process, for instance, may be followed in the analysis of the *sulphuret of arsenic and iron* (1058):

a. Digest 100 grains of the ore in fine powder, in nitric acid, a little diluted, so as sufficiently to moderate its action; a portion of sulphur will remain undissolved, together with silica, if any be present, which may be separated, washed, and burned, in order to obtain the silica.

b. The acid solution containing nitric, sulphuric, and arsenic acids, and oxide of iron, may now be supersaturated with solution of soda, and the precipitate boiled in the alcaline liquor, which, being filtered off, leaves peroxide of iron, by which, when dried and ignited, the equivalent of the metallic iron in the ore is obtained.

c. Neutralize the filtered alcaline liquor with nitric acid, and pour in nitrate of lead, which will give a precipitate of sulphate of lead and arseniate of lead; collect and wash it, and digest it in dilute nitric acid, which will take up the arseniate, but leave the sulphate of lead; the arseniate may again be obtained by saturating with soda.

d. Estimate the sulphur in the sulphate of lead, and add it to that procured by process *a.* 100 parts of the arseniate of lead are equivalent to 56.5 of metallic arsenic.

1472. Mr. Chenevix, in the *Philosophical Transactions* for 1801, has given some valuable details respecting the analysis of several ores of copper; the *native arseniate of copper* (1038) he examined as follows: The ore was first heated to expel and estimate the water; it was then digested in dilute nitric acid, and nitrate of lead poured in, to form arseniate of lead, part of which being held in solution by excess of nitric acid, the liquor was evaporated nearly to dryness, and alcohol added, which occasioned the complete separation of the whole of the arseniate of lead; the remaining solution containing the copper was then boiled with potassa and the oxide of copper collected.

1473. *Arseniate of lead* is omitted in its proper place, at page 210, par. 1038*. It may be formed by pouring arsenic acid into any of the soluble salts of lead, when it falls in the form of a white powder, insoluble in water, but soluble in dilute nitric acid; a circumstance which enables us in analyses to separate it from sulphate of lead, which is insoluble (888.) This compound is fusible without decomposition; but if it be heated with charcoal, both the lead and arsenic are reduced, and the latter evaporates. This compound consists, according to theory, of

Arsenic acid	38.5
Oxide of lead	61.5
	100.

Thenard's analysis (*Annales de Chimie*, i.) gives its component parts

Acid	35.7
Oxide	64.3
	100.0

1474. *Pharmacolite*, or *Native Arseniate of Lime*, was submitted to the following satisfactory analysis by Klaproth.—*Essays*, ii. 221.

a. 100 grains lost, by being moderately heated in a porcelain crucible 22½ grains. As in this operation, neither by the smell nor by the sight, any volatilization of any principle could be observed, this loss of weight must have been caused by the escaping of the water of crystallization. On the other hand, the specimens had undergone no other change by this heating, except their surface being rendered a little duller. But the places spotted red from the cobaltic crust, had now assumed a light-bluish colour.

b. Those 77½ grains which remained after the ignition, dissolved in nitric acid, leaving a grey residue of 6 grains of siliceous, mixed with argillaceous, earth.

c. The filtered nitric solution, which somewhat inclined to the reddish, was evaporated to a smaller volume, and mixed with a solution of acetate of lead as long as any precipitation ensued. The precipitate, when collected, washed and dried at a raised temperature, weighed 138 grains. It consisted of arseniated lead, = 46.5 grains arsenic acid.

d. What remained of the fluid after the separation of the precipitate, together with the washings (*c*) was evaporated to some degree, during which green-coloured borders appeared on the inner surface of the vessel. In order to separate the small quantity of undecomposed acetate of lead, it might yet have contained, I added the requisite quantity of muriatic acid. When, upon farther evaporation no muriate of lead any longer appeared, I mixed the fluid with sulphuric acid. This produced a copious precipitate of sulphated lime, which being collected on the filter, washed with weak spirit of wine, and heated to redness, weighed 54 grains. Therefore, since in 100 parts of ignited gypsum the pure calcareous earth amounts to 42½ parts, the mentioned 54 grains determine the portion of lime contained in the fossil examined at 23 grains.

e. The remainder of the liquor was neutralized with carbonate of soda, and reduced to the state of siccity. On re-dissolving in water the dry saline mass, there remained a powder of the colour of flax-blossoms, and ½ grain of weight, which tinged the borax-glass with a fine deep blue, and thus proved to be an oxide of cobalt.

Those 100 grains of pharmacolite, submitted to this analysis, have, therefore, been decomposed into

Acid of arsenic	46.50
Lime	23
Oxide of cobalt	0.50
Aluminous silex	6.
Water	22.50
	98.50

But since the cobaltic oxide is here but casually admixed, as also the siliceous earth originates merely from the granitic matrix, it follows that, after subtracting these, the proportions of the constituent parts in the pure pharmacolite, are,

Acid of arsenic	50.54
Lime	25
Water	24.46
	100.

SECTION XXIV. *Of the Combinations of Molybdenum.*

1475. THE *native Molybdate of Lead* (1075) was analyzed nearly as follows by Mr. Hatchett:

a. The iron and molybdic acid were separated by the action of hot sulphuric acid; the silica and lead (in the state of sulphate,) were left undissolved.

b. The acid liquor, saturated by ammonia, deposited oxide of iron, which being separated, the whole was evaporated to dryness, and heated to drive off sulphate of ammonia, and the dry residue was pure molybdic acid.

c. The undissolved residue of *a* was boiled with carbonate of soda, and afterwards digested in dilute nitric acid: the carbonate of lead was dissolved, and the silica remained.

d. The nitrate of lead was decomposed by sulphuric acid, and when the sulphate of lead had been separated, the residual liquid was saturated with ammonia, which threw down a small additional portion of oxide of iron.

The results of this analysis were,

Molybdic acid	38.00
Oxide of lead........	58.40
Oxide of iron........	2.08
Silica................	0.28
	98.76

1476. The analysis of the *sulphuret of molybdenum* may be performed by the action of nitric acid, which separates part of the sulphur, and acidifies the remainder as well as the molybdenum; the quantity of sulphur being ascertained by weighing the separated portion, and precipitating by nitrate of baryta that which is acidified, the loss of weight gives the proportion of molybdenum, and the excess of weight of the molybdic acid, above the deficiency, gives the proportion of oxygen united to the molybdenum to constitute molybdic acid. According to Bucholz, the sulphuret of molybdenum is composed of

Molybdenum	60
Sulphur	40
	100

These numbers nearly correspond with the preceding estimate of the composition of this ore (1077); and if we consider it as a bi-sulphuret, it will consist of

1	Proportional of molybdenum ..		= 44
2	.... sulphur	15 × 2	= 30
			74

SECTION XXV. *Of the Combinations of Chromium.*

1477. Two methods of analyzing *Chromate of Lead* (1087) have been pointed out by Vauquelin (*Journal des Mines*, No. 34.) The first consists in repeatedly boiling the finely powdered ore in solution of carbonate of potassa, by which carbonate of lead and chromate of potassa are formed; and the second, by digesting it in muriatic acid, by which muriate of lead is produced, and the chromic acid obtained dissolved in the excess of muriatic acid.

1478. *Chromate of Iron* (1086) is a more refractory compound, but it may be decomposed by the alternate action of potassa and muriatic acid (*Journal des Mines*, No. 55.) The ore, in fine powder, should be heated red hot, with its weight of caustic potassa, for an hour, and the residue washed with water. The insoluble portion may then be boiled in muriatic acid, and, when no longer acted upon, washed, dried, and ignited as before; by the alternation of these processes, it will ultimately be resolved into an alcaline and acid solution; the former, neutralized by nitric acid, lets fall a portion of alumina and of silica, and holds chromate of potassa in solution; add to it nitrate of lead, by which chromate of lead is thrown down, and may be decomposed by muriatic acid. The muriatic solution, evaporated and diluted, lets fall silica, and ammonia throws down oxide of iron and alumina, which may be separated by potassa; evaporate to dryness, and heat to separate muriate of ammonia; the chromic acid remains.

SECTION XXVI. *Of the Combinations of Tungsten.*

1479. *a.* To ascertain the component parts of *Tungstate of Lime*, (1093) Klaproth digested 100 grains of it in fine powder with hot nitric acid, and then decanted the supernatant liquor from the yellow residue; upon which last, after edulcoration, he poured liquid ammonia, and put it in a moderately warm place. This alcali took up that portion of the tungstic oxide, which had been set free by the nitric acid; and thus caused the yellow colour to disappear. The residue was treated twice more, by nitric acid and ammonia. In this way the total decomposition of the fossil was effected; so that only 2 grains of silica remained.

b. The nitric solution was then neutralized with ammonia. But as no change ensued, it was precipitated, in a boiling heat, with carbonated soda; and the precipitate washed and dried. It weighed 33 grains, and consisted of carbonate of lime, which, however, on redissolution in weak nitric acid, deposited 1 grain of silica. 33 grains of carbonate of lime are equivalent to 17.60 grains of lime.

c. The ammoniacal solution afforded, by evaporation in a low heat, slender needle-shaped crystals. When thoroughly desiccated the mass was ignited in a platinum crucible. The tungstic oxide which then remained had the form of a heavy, greenish-yellow powder, and weighed 77$\frac{3}{4}$ grains.

Consequently the 100 grains of tungstate of lime have afforded

Yellow oxide of tungsten (tungstic acid)	77.75
Lime	17.60
Silica	3
	98.35

1480. The examination of *wolfram* (1092) has not as yet been very satisfactorily accomplished, but the analysis of Messrs. D'Elhuyars is probably not far from the truth (*Mémoires de l'Acad. de Toulouse*, ii.) Their result is as follows :

Tungstic acid	64.0
Oxide of manganese	22.0
Oxide of iron	13.5
	99.5

Section XXVII. *Of the Combinations of Columbium.*

1481. The original analysis of the *Columbite* (1086) from North America, by Mr. Hatchett, is detailed in his paper in the *Phil. Trans.* for 1802.

This mineral, which is a compound of the oxides of columbium, iron, and manganese, was rendered soluble by the alternate action of fused carbonate of potassa and muriatic acid; the muriatic solutions contain the iron and manganese, and the columbium is retained in combination with the potassa, from which it may be precipitated by nitric acid.

Dr. Wollaston, in his experiments to show the identity of columbium and tantalum (*Phil. Trans.* 1809,) mixed 5 parts of the ore with 25 of carbonate of potassa, and 10 of borax. The resulting mass was softened with water and digested in excess of muriatic acid, which took up every thing, except the oxide of columbium. The muriatic solution was neutralized with carbonate of ammonia, and the iron separated by succinate of ammonia; after which the manganese was separated by prussiate of potassa. The results of this analysis are given above (1090.)

Section XXVIII. *Of the Combinations of Nickel.*

1482. The separation of nickel from cobalt has already been described (1450) and the analysis of meteoric iron has also been elsewhere adverted to (1126). It remains here to give a general formula for the analysis of ores containing nickel, which is often rendered extremely complex, from the variety of substances united in some of its ores. The following general directions are extracted from Messrs. Aikin's *Dictionary* (Art. Nickel,) and the process has been repeated in the Laboratory of the Royal Institution with sufficiently satisfactory results.

i. The ore being ground to an impalpable powder must be digested with nitric acid considerably diluted; nitrous gas will be given out, and by two or three digestions every thing soluble will be taken up.

ii. The insoluble portion, consisting for the most part of sulphur and silex, is to be dried, weighed, and then heated; the sulphur (*a*) will burn off, and its amount may be ascertained by the difference of weight before and after ignition. The residue after being boiled in a little nitric acid is pure silex (*b*).

iii. Add together both the nitric solutions, nearly saturate the liquor with pure soda, evaporate it considerably, and then pour the solution into cold distilled water, by which the oxide of bismuth (*c*) will be precipitated.

iv. To the filtered solution add muriate of soda drop by drop as long as any precipitate falls down; this is muriate of silver (*d*).

v. Now evaporate the solution nearly to dryness, and boil it with strong nitric acid as long as any nitrous gas is given out: during the process red oxide of iron (*e*) will be precipitated.

vi. Having removed the oxide of iron, nearly saturate the liquor with soda, and pour in nitrate of lead as long as any arseniate of lead (*f*) is precipitated, which separate by the filter.

vii. The nitrous solution being now decomposed by carbonated soda, and the washed precipitate digested in liquid ammonia, oxide of iron (g) mixed with alumine (*h*) will be left behind, which may be separated in the usual way by potassa.

viii. The ammoniacal solution is to be slightly supersaturated with nitric acid, and a bar of iron being immersed in it will separate the copper (*i*); after which the liquor is to be decomposed by carbonated soda, and the precipitate again digested in ammonia, that the iron used for separating the copper may be got rid of.

ix. The solution, containing now only nickel and cobalt, is to be treated according to Mr. R. Phillips's

(*Phil. Mag*. xvi. p. 312,) method, as follows: Evaporate the liquor till the excess of ammonia is driven off, which may be known by the vapour ceasing to discolour moist turmeric paper; then largely dilute it, and pour in pure potash or soda, as long as any precipitation takes place; what falls down is oxide of nickel (*k*).

x. The cobalt (*l*) alone remains in solution, and may be readily separated, by accurately saturating the liquor with nitric acid, and then adding carbonated soda.

The above general mode of proceeding is also applicable to the analysis of *nickel ochre*, except that it should first of all be digested in water, to dissolve out any sulphate of nickel which it may accidentally contain.

1483. The results of the following analysis of the *crystallized sulphate of nickel*, which was made with a view to verify the equivalent number of the metal, are given above (1109).

a. 100 grains of the crystals were heated in a porcelain crucible, to dull redness, for ten minutes; they crumbled into a pale green powder, perfectly soluble in water, consequently no acid had been expelled, and lost 45 grains = water of crystallization.

b. The remaining 55 grains of dry salt were dissolved in two ounces of water, to which nitrate of baryta was added, as long as it occasioned a precipitation; the sulphate of baryta thus formed being collected, washed, dried, ignited, and weighed, amounted to 83 grains = 28.25 sulphuric acid.

c. The filtered solution from which the sulphuric acid had been thrown down in the last process, was now mixed with a little sulphate of soda, to separate excess of baryta, filtered, concentrated by evaporating, and rendered alcaline by potassa; the precipitated oxide of nickel was then thoroughly edulcorated, dried, and exposed to a dull red heat, till it ceased to lose weight; it amounted to 26.5 grains.

The salt, therefore, was thus decomposed into

Water of crystallization....	45.00
Sulphuric acid	28.25
Oxide of nickel	26.50
	99.75

Section XXIX. *Of the Combinations of Mercury.*

1484. What is termed *native mercury* is usually an amalgam, containing a variable portion of silver, and often a trace of gold; it may be analyzed by exposure to heat, which dissipates the mercury, leaving silver and gold, separable by the action of dilute nitric acid.

If the amalgam, besides gold and silver, contain bismuth, its quantity may be judged of by solution in nitric acid, concentration by heat, and pouring the solution into a large quantity of pure water, by which the greater part of the bismuth will be thrown down in the form of white oxide; but the analysis of complex amalgams is much simplified by previously expelling the mercury by heat, taking care that no other metal evaporates with it, which is sometimes the case at high temperatures.

1485. The analysis of *Native Cinnabar* (1166) may be effected in the following manner:

a. Reduce it to powder, and digest it in a sand heat with dilute nitric acid; wash the insoluble portion with hot water, and add the washings to the nitric solution; sulphur will thus be separated, which may be dried and weighed; it may possibly contain silica, and a little oxide of iron; if so, these are left after the combustion of the sulphur, and may be separated by dilute muriatic acid.

b. Add carbonate of potassa in excess to the nitric solution, collect and dry the precipitate, having previously boiled it for a minute or two in the alcaline liquor, and mix it with a little charcoal: put the mixture into a small coated retort, and at a red heat the mercury may be distilled over; the residue may be examined for alumina, lime, oxide of iron, or other extraneous matters.

1486. The *Native Murio-sulphate of Mercury* (1142) may be dissolved in acetic acid, by which a portion of metallic mercury is usually separable from it; nitrate of baryta, added to the acetic solution, separates the sulphuric acid in the state of sulphate of baryta, which being removed, nitrate of silver will throw down chloride of silver; immerse a plate of iron into the remaining solution to precipitate metallic mercury, or throw it down by carbonate of potassa, and distil with a little charcoal.

1487. The *assay* of mercurial ores may be effected by mixing the powdered sample with half its weight of a mixture of equal parts of lime and iron filings, and submitting it to distillation in the open fire, in a coated glass retort.

Section XXX. *Of the Combinations of Silver.*

1488. As instances of the analysis of complex silver ores, I have selected that of the bismuthic silver, and of the white silver ore, from Klaproth (*Essays*, i. 556, 145.) whose paper on the composition of various silver ores may be strongly recommended to the attentive perusal of the student.

a. Upon 300 grains of the *Bismuthic Silver* from Schapbach, in the Black Forest, I poured three ounces of nitric acid, diluted with one of water; a great part of it dissolved, even in the cold; the residue was again digested with one ounce of the same acid, in a gentle heat; both solutions were filtered, mixed, and evaporated to a smaller volume; during which process there separated some crystalline grains of nitrate of lead.

b. The concentrated solution had a greenish colour; when diluted with as much water as was requisite to re-dissolve that crystalline sediment, it was poured into a large quantity of water; this immediately acquired a milky appearance, and deposited a white precipitate, which weighed 44.5 grains, when collected, lixiviated, and dried in the air, and proved on further examination to be oxide of bismuth.

c. Into the liquor that had been freed from this oxide, and was clear and colourless, I dropped muriatic acid, as long as it was rendered turbid by it: the precipitate did not appear to be mere muriate of silver, for this reason I digested it with nitric acid; a considerable portion was thus re-dissolved, and left pure horn-silver behind; which, upon careful collection, and desiccation in a brisk heat, weighed 46 grains: thus, the portion of pure silver is determined at 34.5 grains.

d. The nitric acid, that had been affused upon the precipitate obtained by the muriatic *c*, yielded by dilution with much water 32 grains more of oxided bismuth; which, with the preceding 44.5 *b*, gave together 76.5 grains.

e. The remainder of the fluid was farther reduced by evaporation, and in this process muriate of lead separated from it in crystals; this liquor was then combined with such a quantity of sulphuric acid as was requisite to re-dissolve those crystals, and a second time evaporated; the precipitate which thence ensued was sulphate of lead, weighing 19 grains, when duly collected, washed, and dried.

f. What still remained of the solution, after its having been freed from the lead before contained in it, was saturated with caustic ammonia added in excess: in this way a brown ferruginous precipitate was produced, which was rapidly attracted by the magnet, and weighed 14 grains, when, after previous desiccation, it had been moistened with linseed oil, and well ignited: for these we must reckon 10 grains of metallic iron.

g. The liquor which had been supersaturated with ammonia, and which by its blue colour shewed that it held copper in solution, was next saturated to excess with sulphuric acid; on immersing then a piece of polished iron into it, two grains of copper were deposited.

h. The grey residue of the ore, that was left behind by the nitric acid *a* weighed 178 grains; but when its sulphureous part had been deflagrated in a crucible gently heated, it weighed only 140.5 grains; this determines the portion of sulphur at 37.5 grains.

i. These 140.5 grains were digested with 3 ounces of muriatic acid in a heat of ebullition, and this process was repeated once more with 1.5 ounces of the same acid; these solutions, by means of evaporation, yielded muriate of lead in tender spicular, and likewise in broad-striated, crystals; which, when again dissolved in the requisite quantity of boiling water, then combined with sulphuric acid, and evaporated, yielded 89 grains of sulphated lead; thus the whole quantity of this sulphate, including the 19 grains mentioned at *e*, amounted to 108 grains; for which, according to comparative experiments, 76 grains of reguline lead must be put in the computation.

k. That portion of the ore examined, which still remained after all the constituent parts beforementioned have been discovered, consisted merely of the grey quartzose matrix, the weight of which, in the ignited state, amounted to 70 grains.

Therefore those 300 grains of bismuthic silver ore mentioned above were decomposed into

Lead, *i*	76.
Bismuth, *d*	62.20
Silver, *c*	34.50
Iron, *f*	10.
Copper, *g*	2.
Sulphur, *h*	37.50
Quartzose matrix, *k*	70.
	292.20

It follows, from this statement, that, exclusively of the quartzose gangue, the constituent parts of the bismuthic silver are in the 100,

Lead	33.
Bismuth	27.
Silver	15.
Iron	4.30
Copper	0.90
Sulphur	16.30
	96.50

1489. Klaproth treated the *white silver ore* from Freyberg, nearly as follows:

a. The ore was brittle, and easily levigated into a blackish powder.

b. Upon 400 grains in powder he poured 4 ounces of nitric acid, and 2 of water; after sufficient digestion in a gentle heat, the solution was decanted, and the residue again treated with 2 ounces of the acid; this mixture was next diluted with eight parts of water, and digested for some time; he then separated the undissolved residue, consisting of a greyish-white powder, which, after washing and drying, weighed 326 grains.

c. The solution, which was nearly colourless, was combined with common salt, by which muriated silver was produced; and the next day crystals of muriate of lead were found; on this, therefore, he boiled the whole precipitate in a large quantity of water, by means of which the muriated lead was re-dissolved, and separated from the muriate of silver, collected on the filter: this last, when reduced by fusion with soda, yielded 81.5 grains of reguline silver.

d. What remained of the solution, together with the liquor obtained by the decoction of the horn silver, he evaporated in part; and by adding a saturated solution of sulphate of soda, obtained from it 45 grains of sulphate of lead, which, upon reduction, afforded 32 grains of lead in the metallic state.

e. The remaining part of the solution was saturated with pure ammonia, upon which a light-brown precipitate fell, weighing 40 grains, when edulcorated and ignited in a low heat; as that precipitate had the appearance of a mixture of iron and alumina, he dissolved it again in nitric acid, and precipitated first the iron by prussiate of potassa, and afterwards, by the addition of soda, a loose earth, which, when desiccated and ignited, weighed 28 grains, and upon trial with sulphuric acid, was found to be aluminous earth; this being subtracted from the above 40 grains, leaves 12 for the oxide of iron, which may be estimated at 9 grains of metallic iron.

f. After this the residue that remained from the solution of the ore, dissolved in nitric acid *b,* was subjected to a closer examination: Klaproth attempted to decompose it by muriatic acid, repeatedly poured upon it, and in every instance digested over it in a heat of ebullition. The process was rendered somewhat difficult by the crystals, which were deposited from the solution as soon as the heat fell below the boiling point; similar crystals likewise shot on the paper, through which the solution, though yet boiling, was filtered, and he gradually re-dissolved them in warm muriatic acid; at last there remained 51 grains of sulphur, leaving, after deflagration upon a test, two grains of a grey residue, one of which dissolved in muriatic acid, and was added to the preceding solution; the other grain was siliceous earth. The true quantity of the sulphur, therefore, amounted to 49 grains.

g. While the muriatic solution was cooling, it deposited a quantity of acicular crystals; these being separated, one half of the remaining fluid was distilled over in a small retort, and from the solution thus concentrated more crystals similar to the first were deposited; this treatment was continued until no more crystals would form; when these crystals, collected together, were mingled with twice their weight of black flux, and reduced in an assay-crucible, thinly lined with charcoal-dust, they afforded 160$\frac{5}{8}$ grains of lead; this lead, subjected to cupellation, emitted at the first application of heat a few antimonial vapours; it then fined quietly, and left a button of silver, weighing $\frac{1}{8}$ of a grain: this determines the proportion of lead at 160.25 grains; from which, however, a trifling quantity should be deducted for the portion of antimony before-mentioned, though it could not be well determined, besides that it could not weigh much above half a grain.

h. The fluid separated from the muriate of lead, concentrated, and diluted with a large quantity of water, deposited its metallic part, which, in the form of a subtle white powder, was only oxide of antimony, and being kneaded into a mass with soap, was reduced in a luted assaying-crucible, by means of black flux, into 28.5 grains of pure reguline antimony; some more small globules were found adhering to the lid of the vessel, of which I collected 3 grains; but still a small portion appeared to have escaped through the joinings, and for this reason, the true amount of antimony which I obtained may be reckoned at somewhat more than the 31.5 grains.

Hence the product of the 400 grains of the white silver ore here analyzed consisted of

Silver	*c*	81½	81⅝ grs.
	g	⅛	
Lead	*d*	32	192¼
	g	160¼	
Reguline antimony, *h*			31½
Iron, *e*			9
Sulphur, *f*			49
Alumina, *e*			28
Silex, *f*			1
			392⅜

Which in 100 parts makes

Silver	20.40
Lead	48.06
Antimony	7.88
Iron	2.25
Sulphur	12.25
Alumine	7.
Silex	0.25
	98.09

SECTION XXXI. *Of the Combinations of Gold.*

1490. IN the Section on the combinations of Tellurium, I have quoted Klaproth's analyses of some of its ores containing gold; the only proper ore of this metal is *native gold*, (1259) which is occasionally found in veins, but of which by far the greatest proportion occurs dispersed in a granular form through certain alluvial strata. In this state, silver and copper are the principal metals with which it is combined, and the analysis is sufficiently simple; the ore may be digested in nitro-muriatic acid; the solution evaporated nearly to dryness, and again diluted, leaves the silver in the state of chloride; a strong solution of proto-sulphate of iron may then be used to throw down the gold (1260), and the copper may be separated by immersing a plate of iron into the last filtered liquor.

If the proportion of silver and copper alloyed with the gold be considerable, the analysis may be simplified by using nitric acid in the first instance, which extracts the silver and copper, leaving the gold untouched: muriatic acid may then be poured in to throw down the silver, and the copper separated by iron, as before; or by precipitation by potassa, and ignition, which gives it in the state of peroxide.

SECTION XXXII. *Of the Combinations of Platinum.*

1491. WE are indebted to Dr. Wollaston and to Mr. Tennant (*Phil. Trans.* 1803.) for our knowledge of the component parts of the *ore of platinum,* as imported from South America. In this state it generally contains the following metals, exclusive of small particles of silica, and a variable portion of mercury, *viz.*: platinum, gold, palladium, rhodium, iridium, osmium, iron, copper, and lead; and the following is the process for their separation:

The mercury may be driven off by heat, a process which renders the platinum yellower in consequence of the appearance of the grains of gold; it may then be digested in nitro-muriatic acid diluted with its bulk of water, which takes up gold, iron, and a little platinum; if the remaining ore be now digested in nitro-muriatic acid, by far the largest portion will be dissolved, and there will remain a black powder: to the nitro-muriatic liquor add a solution of muriate of ammonia, which will occasion the separation of the greater part of the platinum in the state of a very difficultly soluble ammonio-muriate, and which may be separated upon a filter; in the filtrated liquor immerse a plate of zinc, which will throw down lead, rhodium, palladium, and a portion of platinum; the lead may be separated by very dilute nitric acid; dissolve the residue in nitro-muriatic acid, add common salt, and evaporate to dryness; this residue, composed of the *soda-muriates of platinum, palla-*

dium, and rhodium, is to be digested in alcohol, which dissolves the triple salts of platinum and palladium, but not that of rhodium (1197), which therefore is thus separated; to the alcoholic solution add solution of muriate of ammonia, which throws down the platinum, and leaves the palladium in solution, which may be precipitated by ferrocyanate of potassa (1200).

The insoluble black powder, by alternate fusions with potassa, and boiling in muriatic acid, is resolved into *osmium* (1190) soluble in the alcali, and *iridium* (1193) in the acid.

SECTION XXXIII. *Of Siliceous and Aluminous Combinations.*

1492. THE ready solubility of silica by fusion with the fixed alcalis, and its insolubility in the greater number of the acids, render its separation in most cases of analysis extremely easy. Muriatic acid, under certain circumstances, is capable of retaining a considerable quantity of silica, and the solution, when evaporated, assumes a gelatinous appearance; if ammonia be then added, and the whole evaporated and heated red-hot, the silica is obtained pure, and not again soluble in the acid.

1493. Alumina, like silica, is soluble in potassa, and the addition of acids to the mixed alcaline solution throws down a compound which is not entirely decomposed by the action of those acids, which, under ordinary circumstances, readily dissolve alumina without acting upon silica; a circumstance of which it is necessary to be aware, in certain cases of analysis.

1494. If silica is predominant in a stone, it is in general rendered easily soluble by heating it in fine powder with potassa; but there are some of the hard aluminous compounds which are very difficultly acted on in this way; Mr. Chenevix found minerals of this class were most readily attacked by borax. One part of the mineral in fine powder, mixed with about three parts of glass of borax, is to be strongly heated in a platinum crucible; the contents, when cold, are perfectly soluble by long digestion in muriatic acid; the addition of carbonate of ammonia throws down the dissolved earths, which may be collected, re-dissolved, and examined as usual. Sir H. Davy has, in similar cases, recommended the use of boracic acid.—*Phil. Trans.* 1805.

1495. There are a few minerals which contain fluorine, or fluoric acid, (646) the presence of which is ascertained by heating the substance in fine powder with sulphuric acid, either before or after its fusion with potassa, when vapours which act upon and corrode glass will be liberated. To ascertain the proportion of fluoric acid in a mineral, it may be fused with potassa, and treated by muriatic acid, to separate silica; to the remaining liquid add excess of carbonate of potassa, and filter, neutralize the filtrated liquor with muriatic acid, and add muriate of lime, which will occasion a precipitate of fluate of lime, the purity of which is to be ascertained, and the quantity of fluorine and fluoric acid inferred from it.

1496. Boracic acid, originally found in the *Bo-*

racite (696) by Westrumb, has also been discovered by Klaproth in *Datolite* (xxiv. p. 319.) and in *Botryolite,* and more lately by Arfwedson and Berzelius in the *green Tourmaline* and *Rubelite.* The following is a sketch of M. Arfwedson's analysis:

A portion of the green tourmaline in fine powder, was strongly heated for an hour, with four times its weight of carbonate of baryta; the mass was dissolved in muriatic acid, and the solution evaporated to dryness; water, acidulated with muriatic acid, then dissolved every thing but the silica.

The baryta was separated from the solution by sulphuric acid, and the other earths, with the oxides of iron and manganese, by an excess of carbonate of ammonia; the solution being separated from the precipitate, and evaporated to dryness, a sulphate was obtained, which, when again treated with ammonia as before, dried, and heated red, re-dissolved in water without leaving any residuum; this solution was freed from its sulphuric acid, by acetate of baryta, and the filtered liquid evaporated; a gummy mass was obtained, which, by calcination in a platinum crucible, was decomposed, and afforded a fused alcaline mass, which proved to be lithia. "I began to consider my work almost finished, (adds Mr. Arfwedson) when, on drying and heating a portion of the alcaline solution, I observed, at the moment the mass began to fuse, that it swelled up like borax, and left a glass, after calcination, of the same appearance as vitrified borax; it was very probable, therefore, that the mineral contained boracic acid, and I ascertained it by heating the fused mass with muriatic acid, which gave me, by evaporation, a salt, partly soluble in alcohol, to which it imparted the property of burning with the greenish flame so characteristic of boracic acid."

To obtain the quantity of this acid, a portion of the mineral was fused with bi-sulphate of potassa; the mass boiled with alcohol, and the filtered liquid evaporated to dryness; a substance remained equal to 1.1 *per cent.* of the weight of the tourmaline, and having all the properties of boracic acid.—*Annales de Chimie*, Vol. x., p. 98.

1497. To the above observations, I shall add, as specimens of practical analysis, two instances from Klaproth's *Essays*, *viz.*, his analysis of the *Spinell* and of *Kryolite:*

a. 100 grains of rough spinell from Ceylon, in picked crystals, previously pounded to a coarse powder in a steel mortar, were triturated with water to an impalpable powder in a grinding-dish made of flint; after the powder of the stone, which was again dried, had been gently ignited, it shewed an increase of weight of nine grains, arising from the particles abraded from the substance of the grinding-vessel.

b. I then digested the powder with two ounces of muriatic acid; when the acid was evaporated nearly to dryness, I diluted the mass with water, threw it upon the filter, and saturated the yellow muriatic solution with caustic ammonia; a brown flocculent oxide of iron fell down, which, collected and ignited, weighed 1.25 grains.

c. The liquor separated from that precipitate was concentrated by evaporation, perfectly neutralized with muriatic acid, and lastly combined with dissolved oxalate of potassa; in consequence of this, oxalate of lime precipitated, which, when carefully collected, and heated to redness in the cavity of a compact piece of charcoal, with the assistance of the blowpipe, afforded .75 of a grain of lime.

d. Upon the powder of the stone, extracted by the muriatic acid, was poured ten times its quantity of alcaline ley, one half of which consisted of caustic potassa, which mixture being first evaporated to dryness in a silver vessel, was afterwards ignited during the space of an hour; when the mass had been again softened with hot water, it left on the filtering paper 54 grains of a yellow residue when dried in the air.

e. These 54 grains were a second time mixed, and inspissated with a tenfold quantity of the same caustic lixivium, and afterwards ignited; upon which the mass, softened again with water, deposited a residue of a fine pulverulent form, weighing 43 grains when dried in the air.

f. I then neutralized the yellow alcaline solution (*d* and *e*) by means of sulphuric acid, and by affusing more acid, made a clear solution of the precipitate, which then formed; carbonate of potassa added in a boiling state threw down from it a precipitate of a very great bulk, which after edulcoration was again dissolved in sulphuric acid; this solution exhibited a slimy toughness, but it became perfectly fluid, when exposed to a raised temperature, and deposited a subtle white powder, which, after washing and desiccation in the air, weighed 95 grains: the sulphuric acid fluid, when separated from it, was set aside for a time.

g. The above-mentioned 95 grains were then gently ignited with thrice their quantity of caustic potassa;

when again liquefied with water, and filtered, there remained only a slight residue, which, after washing, dissolved in sulphuric acid, with the exception of a few remaining particles.

h. The portion taken up by the potassa in the alcaline solution *g* was precipitated by means of sulphuric acid ; but it dissolved again in the acid, when added to excess, and was afterwards precipitated by boiling with carbonated alcali: this precipitate, previously washed, was once more dissolved in sulphuric acid.

i. The whole of the sulphuric solutions, obtained at *f g h,* was evaporated to a smaller compass ; the gelatinous consistence into which it congealed shewed that a separation of siliceous earth had taken place: it was therefore largely diluted with water, digested, and the silex collected upon the filter.

k. This done, the sulphuric solution was put in a state to crystallize, by dropping into it a solution of acetate of potassa, and evaporating it slowly ; it yielded at first regular and pure crystals of alum ; but as the solution assumed a green colour towards the end, I combined it with Prussian alcali ; a trifling precipitation ensued, of which the oxide of iron could not be estimated more than at one-fourth of a grain ; the solution, being now freed of its ferruginous ingredient, was next decomposed in a boiling heat by carbonated potassa, and the precipitate, when dissolved anew in sulphuric acid, was brought to a final crystallization, after which the alum then obtained was added to the foregoing.

l. I now proceeded to the analysis of the 43 grains, that were left undissolved by the caustic alcaline ley *e*. These readily dissolved in dilute sulphuric acid, leaving some siliceous earth behind; the solution, separated from this last, was then combined with a small portion of acetated potassa, and exposed to spontaneous crystallization by exhalation in the open air. At first there yet appeared some solitary crystals of alum; but afterwards it entirely shot into sulphate of magnesia (Epsom salt).

m. To separate the sulphated magnesia, thus obtained, from the admixed alum, it was strongly ignited in a porcelain vessel during half an hour, and the saline mass afterwards softened in water, and filtered; the aluminous earth, separated by this management, was afterwards dissolved in sulphuric acid, and in the proper manner crystallized into concrete alum.

n. The pure solution of the sulphated magnesia was precipitated in a boiling heat by means of vegetable alcali. The magnesian earth, thus obtained in a carbonated state, weighed 20.5 grains when washed and dried; but after strong ignition it weighed only 8.25 grains.

o. All the washings (of which that at *f*, on precipitating the sulphuric solution by carbonate of potassa, retained the yellow colour of the first solution) were together evaporated to a dry saline mass; when they had been re-dissolved in water, there still separated a little earth, which, along with the precipitate remaining at *g*, was ignited with caustic potassa, and then by sulphuric acid resolved into aluminous and siliceous earths.

p. The whole quantity of alum, obtained at *k l m* and *o*, amounted to 665 grains. It was now dissolved in water, and in a heat of ebullition decomposed by carbonate of potassa. The aluminous earth thus obtained, when edulcorated with water, and dried in a moderate warmth, weighed 221 grains; but after being purified by digestion with distilled vinegar, and subsequent saturation with ammonia, and being again edulcorated, and at last subjected for half an hour to an intense red heat, it weighed no more than 74.5 grains.

q. I then ignited, for half an hour, the whole of the siliceous earth collected from *i l o*: its weight was 24.5 grains. Hence, subtracting the 9 grains which had been abraded from the flint-mortar *a*, there remained 15.5 grains belonging to the spinell.

From this analysis it follows, that the constituent parts of the spinell in the 100 are

Alumine, *p*		74.50
Silex, *q*		15.50
Magnesia, *n*		8.25
Oxide of iron	*b* .. 1.25 *k* .. 0.25	1.50
Lime, *c*		0.75
		100.50

The reason why, in this instance, there appears in the sum of the weights an excess of half a grain, rather than a loss, unavoidable in the usual course of such processes, is probably, that the ignition was not powerful enough to effect in those ingredients that high degree of dryness, which that stone possesses in its natural undecomposed state.

1498. *Analysis of the Kryolite*; after some preliminary experiments, which taught him the existence of fluoric acid, soda, and alumina in this mineral, Klaproth proceeded as follows:

i. 100 grains of triturated kryolite, to expel entirely the fluoric acid, were inspissated to dryness in a platinum crucible, with 300 grains of concentrated sulphuric acid. The residual mass, previously drenched with water, congealed on evaporation to a soft, granular saline mass, which readily liquefied in a little water.

ii. Caustic ammonia precipitated from the clear solution the aluminous earth weighing 46 grains, when edulcorated and dried, but 24 grains when ignited. The solution of this earth, in dilute sulphuric acid, with the assistance of heat, and combined with a just proportion of potassa, shot into regular crystals of alum.

iii. The fluid, from which the alumina had been precipitated, was neutralized with acetic acid, then combined with acetated baryta, and filtered, to separate the barytic sulphate. The clear fluid was now wholly evaporated, its dry residuum ignited in a platinum crucible, re-dissolved, and, after being rendered free by filtration, from the few adhering coaly particles, a second time evaporated to perfect dryness. It thus afforded $62\frac{1}{2}$ grains of dry carbonate of soda, equal to 36 grains of pure soda. This, saturated with acetic acid, crystallized all to acetate of soda.

If now, from the quantity of the fossil employed, be subtracted the weight of alumina and soda obtained, the remainder will give the weight of the fluoric acid, including perhaps the water of crystallization. 100 parts of kryolite, therefore, consist of

Soda	36
Alumina	24
Fluoric acid, including the water	40
	100

Section XXXIV. *Of the Combinations of Zirconium.*

1499. Klaproth's description of the discovery of zirconia, and of the method of separating it from the Jargon and Hyacinth of Ceylon, contain a very instructive lesson in analytical chemistry; in those minerals the zirconia is combined with silica, and with a trace of oxide of iron; the following mode of obtaining pure zirconia, suggested by MM. Dubois and Silveira (*Annales de Chimie et Phys.* xiv.) furnishes, at the same time, a process for the analysis of the mineral, upon the whole less exceptionable than that of preceding chemists.

Reduce the zircons to fine powder, and heat them in a red heat for an hour, with two parts of pure potassa; pour distilled water on the fused mass, and wash the insoluble portion upon a filter; dissolve it in muriatic acid, and evaporate to dryness; pour water on the residue, which leaves silica, and dissolves muriate of zirconia and iron; filter, and add ammonia, which throws down zirconia and oxide of iron: wash the precipitate and boil it, while moist, in a solution of oxalic acid, which retains the iron, and forms an insoluble oxalate of zirconia; collect and edulcorate the latter, and heat it to redness in a platinum crucible: in this state the zirconia, though pure, is insoluble in acids; fuse it, therefore, with potassa, wash away the alcali, dissolve in muriatic acid, and precipitate by ammonia; the *hydrate of zirconia* now thrown down, when washed and dried, is pure and soluble.

SECTION XXXV. *Of the Combinations of Glucinum.*

1500. THE composition of the beryl, and of the emerald, and the mode of obtaining from them pure glucina have been given above (1343); in this section therefore I shall merely give Klaproth's examination of the emerald, as showing the mode of separating glucina in analyses.—*Essays*, ii. 177.

a. 100 grains of light-green emerald were levigated in a flint mortar, by which their weight increased $2\frac{1}{2}$ grains. The powder of the stone was mixed with a solution of 250 grains of caustic soda, and inspissated in a silver crucible; upon which the dry mass was moderately ignited during 30 minutes.

b. When this mass had cooled, it appeared white, and not easily softened in water. It was saturated to excess with muriatic acid, which effected a solution. This being evaporated, and afresh diffused in water, was thrown upon the filter, in order to collect the siliceous earth, which, washed, dried, and ignited, weighed 68 grains, after deducting the 2½ grains it received from the mortar.

c. The muriatic solution was supersaturated with soda and boiled. The precipitate was soon again taken up by the fluid, excepting some loose ash-grey flocks, which, upon drying and ignition, weighed 2½ grains. As the filtering paper, upon which this residue has been collected, was coloured brownish, it was extracted with a little weak muriatic acid, and the solution treated with prussian alcali, which produced a blue precipitate of iron.

d. Upon those 2½ grains of the brownish residuum nitric acid was poured and again driven off by heat, after which potassa was affused. This took up but a little, and the residuum, again washed and ignited, lost only $\frac{3}{10}$ of a grain. The alcaline fluid was neutralized with nitric acid, and one-half of it combined with acetated lead, the other half with nitrate of silver. By the lead a lemon-yellow, and by the silver a brown-red precipitate was obtained. Thus the portion of chrome in emerald was separated and obtained singly.

e. The brown residue of *d* was dissolved in muriatic acid, but the solution, acted on by a low heat, soon coagulated into a jelly-like substance, owing to the siliceous earth which separated, and upon ignition weighed ½ gr. The fluid, freed from this, was then treated with a solution of succinate of soda. The precipitate, obtained by this means, when edulcorated and dried, gave 1 grain of oxide of iron.

f. As to the alcaline solution *c*, I mixed it with the remaining fluid of *e*, supersaturated the mixture with muriatic acid, and precipitated it in an ebullient heat with carbonated soda. The precipitate here obtained I dissolved in sulphuric acid, and after having combined it with acetate of potassa, forwarded it to crystallization. The first shootings yielded alum, in pure crystals; but on subsequent evaporation sulphate of lime appeared, which, in the ignited state, weighed ¾ of a grain, equivalent to ¼ of pure lime. What still remained of the fluid had now a thick oily consistence; diluted with a little water, and exposed to spontaneous crystallization, it afforded crystals, but they had not the form of alum.

g. This saline mass, together with the alum already obtained, was dissolved in water, and a large quantity of carbonate of ammonia affused, upon which I stoppered the vessel. After it had stood 24 hours, I separated the remaining earth by means of the filter, dissolved this last again in sulphuric acid, and, lastly, extracted it by adding a great over-proportion of carbonated ammonia. When the earth had again been separated, it was a second time subjected to the same treatment; after which nothing more was taken up by the ammonia.

h. The aluminous earth, was now heated to redness; it then amounted to 15¾ grains.

i. From the ammoniacal fluid, which had been collected from those reiterated extractions, the superabundant alcali was distilled off, until the quantity of the white earth, which parted from the fluid, no longer increased. This earth, washed and dried, weighed 23½ grains; after ignition its weight proved to be 12½ grains.

When re-dissolved in sulphuric acid, and left to spontaneous evaporation, it formed oblique, quadrilateral double pyramids, with truncated edges and corners. The saccharine taste of these crystals, in conjunction with their other properties, shewed that the base of this salt was glucine, the new earth discovered by Vauquelin in the beryl.

Hence this decomposed emerald has yielded, as its constituent parts,

Silex	*b* 68 *e* 0.50	68.50
Alumine	*h*	15.75
Glucine	*i*	12.50
Lime	*f*	0.25
Oxide of iron	*e*	1
Oxide of chrome	*d*	0.30
		98.30

SECTION XXXVI. *Of the Combinations of Yttrium and Thorinum.*

1501. I HAVE not been able to collect any information relative to the analysis of the compounds containing yttria, which would assist the student in their examination, in addition to that which has been given in the preceding Chapter, where I have enumerated the distinctive characters of yttria, and the mode of separating it from its combination with other earths (1346).

1502. Thorina, found by Berzelius in the Gadolinite of Koraruet, and in two other Swedish minerals, which he terms *deuto-fluate of cerium,* and *double fluate of cerium* *and yttria*, has not hitherto been examined by any other chemist; indeed, the discoverer has himself obtained it in such small quantities as to have enabled him to furnish but an imperfect account of its properties. In addition, therefore, to the distinctive characters of thorina given above (1349) I shall here only add the process by which it was procured.

To the solution of the mineral add succinate of ammonia to throw down the iron; then pour in sulphate of potassa to precipitate the cerium, and afterwards ammonia will separate the yttria and thorina; to separate these substances re-dissolve them in muriatic acid, and evaporate till the solution is as nearly neutral as possible, then pour water upon it and boil for an instant; thorina is precipitated, and the liquid becomes acid: by saturating this acid, and boiling again, an additional portion of thorina precipitates.

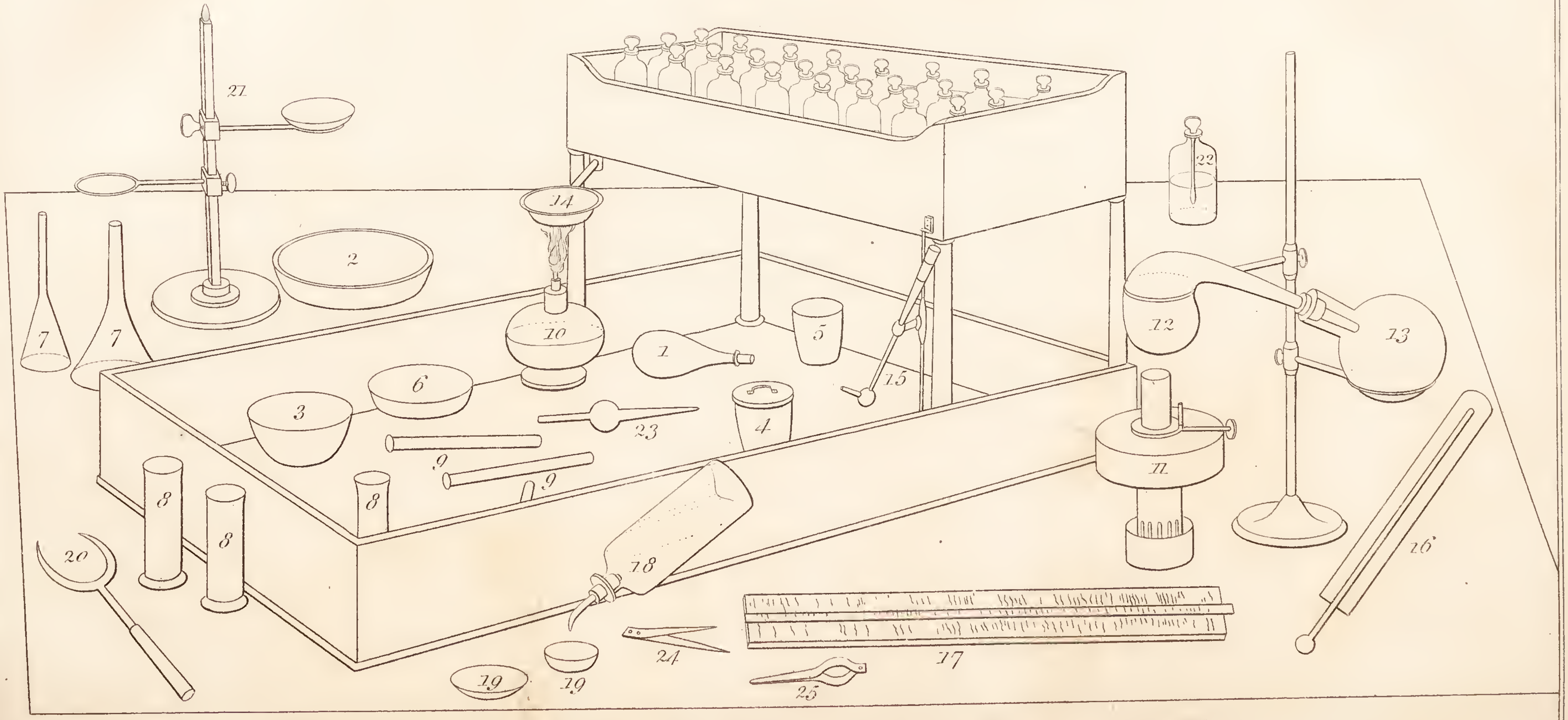
These details are, it must be confessed, very unsatisfactory: and when we reflect upon the complex nature of the substances submitted to analysis, upon the prolixity of the process, upon the small quantity of thorina hitherto procured (not amounting, according to Dr. Thomson (*System*, i. 377, 6th *Edit.*) to 7 grains and a half,) and upon the acknowledgment that it is only occasionally present in the minerals adverted to, we may perhaps be inclined to doubt its distinct nature

CHAPTER VII.

OF THE ANALYSIS OF MINERAL WATERS.

1503. The following observations, relating to the analysis of mineral waters, have been drawn up principally with a view to facilitate the progress of the student, in that very difficult department of analytical chemistry. I have endeavoured to simplify the details by pointing out the readiest methods of recognising and separating the substances which usually occur, and have, therefore, omitted the enumeration of the more rare ingredients, or of those which are limited to particular places.

I have not adverted to the mode recommended by Dr. Murray (*Edinburgh Phil. Trans.*, viii.) because I cannot readily admit the existence of incompatible salts to the extent which his principle requires; nor do I think that it materially facilitates the analysis in those cases which present peculiar difficulties to the plan of determining the ingredients by evaporation.



Portable Laboratory for the Analysis of Mineral Waters.

M. F

Published by John Murray, Albemarle Street, London March 1821.

J.s Basire sc.

SECTION I. *Of the Tests and Apparatus required in the Examination and Analysis of Mineral Waters.*

1504. THOSE who have not access to a regular laboratory will find it convenient to arrange the following tests and re-agents in the manner represented in Plate I. of this volume, the larger phials should contain about 6 ounces by measure; the second size, 3 ounces; and the smallest, 1 ounce. Of these phials, the greater number should be simply stopped, and a few of them provided with an elongated stopper dipping into the fluid which they contain.

The larger phials may contain the following re-agents:

Pure sulphuric acid.
—— nitric acid.
—— muriatic acid.
Dilute sulphuric acid, 1 acid + 3 water.
——— nitric acid . . . . . . ditto.
——— muriatic acid . . . . ditto.
Solution of potassa.
——— soda.
——— ammonia.
——— carbonate of potassa.
——— carbonate of soda.
——— carbonate of ammonia.
——— oxalic acid.
——— oxalate of ammonia.
——— baryta.
——— acetate of baryta.

Solution of nitrate of baryta.
——— phosphate of soda.
——— sulphate of silver.
Alcohol.

The smaller phials may contain

Tincture of galls.
Solution of iodine in alcohol.
——— nitrate of silver.
——— ferro-cyanate of potassa.
——— muriate of lime.
——— hydro-sulphuret of ammonia.
——— hydriodate of potassa.
——— soap in alcohol.
Phosphorus.
Sulphate of lime.
Test-papers, turmeric, litmus, violet.
Black flux.
Nitrate of ammonia.

The tray should contain a few Florence flasks (1), Wedgwood and glass basins (2, 3), a platinum and a silver crucible (4, 5), a silver capsule (6), some funnels (7), test-glasses (8), test-tubes (9), and glass rods, filtering paper, a spirit (10), and an Argand lamp (11), a retort (12), and receiver (13), a copper basin to serve as sand-bath (14), a blow-pipe (15), a thermometer (16), a scale of equivalents (17), a dropping-bottle (18), a few watch-glasses (19,) a support for holding glasses over a lamp (20), a small brass stand with rings (21), a tube, with a bulb in the centre and a pointed extremity, for drawing up small portions of liquids (23), platinum pincers (24, 25); a small but good balance, with well-adjusted weights, is also requisite, accompanied by a phial and counterpoise for taking specific gravities; and, lastly, a small mercurial trough. There should also be a plentiful supply of distilled water, a portion of which should be contained in a dropping-bottle.

Section II. *Examination of Mineral Waters by Tests.*

1505. i. The term *mineral water* is applied to those natural spring-waters which contain so large a proportion of foreign matter as to render them unfit for common domestic use, and to confer upon them a sensible flavour, and specific action upon the animal frame. Their temperature is liable to considerable variation, and is sometimes their principal character, as is the case with the waters of Bath and Buxton; but they are generally so far impregnated with acid or saline bodies, as to derive from them their peculiarities, and in this respect may conveniently be arranged under the heads of *carbonated, sulphureous, saline,* and *chalybeate* waters. See the annexed Table (1507.) The mere taste of the water enables us to determine to which of these subdivisions it probably belongs.

ii. In examining a mineral water, it is of importance to ascertain its specific gravity, which gives us some insight into the proportion of its saline ingredients, its specific weight, as compared with pure water, being of course augmented by its foreign contents. Mr. Kirwan (*Essay on Mineral Waters*, p. 145.) has given the following formula for calculating the proportion of saline substances in a water of known specific gravity: " subtract the specific gravity of pure water from that of the water examined, and multiply the remainder by 1.4. The product is equal to the saline contents in a quantity of the water denoted by the number employed to indicate the specific gravity of distilled water. Thus suppose the specific gravity of the water = 1.079, and that of pure water = 1.000, then 79 × 1.4 = 110.6 = saline contents in 1000 of the mineral water."

This is a useful formula, but open to certain objections; and as it is often of considerable importance to acquire a just knowledge of the proportion of foreign bodies in water, it is advisable to conjoin the above method with the following:

iii. Evaporate a given weight, say 1000 parts, to dryness, and expose the residue for 24 hours to a temperature not exceeding 300° upon a platinum capsule; weigh it while warm, and the mean obtained from this and the former experiment, will give the proportion of dry saline ingredients within an error of two *per cent.* Thus suppose 1000 parts of the above-mentioned water give by evaporation 114.4 dry residue, then $110.6 + 114.4 = 225 \div 2 = 112.5$ = quantity of saline matter in a dry state (salts deprived of water of crystallization) existing in the mineral water under investigation.

iv. Having by these preliminary operations ascertained the relative *quantity* of foreign matter in the water under examination, the *nature* of the substances present is next to be inquired into.

1506. The substances which have been found in mineral waters are extremely numerous, but those which ordinarily occur, are the following:

Oxygen.
Nitrogen.
Carbonic acid.
Sulphuretted hydrogen.
Carbonate of lime.
Carbonate of magnesia.
Carbonate of iron.
Muriate of magnesia.
Sea salt.
Sulphate of magnesia.
Sulphate of soda.
Sulphate of lime.

a. Oxygen and nitrogen exist in the greater number of spring waters in the proportions constituting atmospheric air; the proportion of nitrogen is, however, not unfrequently predominant. These gases give no peculiar flavour to the water.

b. Carbonic acid renders mineral waters sparkling and effervescent: it is detected by occasioning a precipitate in aqueous solution of baryta, which dissolves with effervescence in dilute muriatic acid.

c. The presence of sulphuretted hydrogen is known by its peculiar disagreeable smell; by the production of a black precipitate on dropping into the water a solution of nitrate of silver; and by the deposition of sulphur on adding a few drops of nitric acid.

d. The carbonates are dissolved in the water by excess of carbonic acid, and consequently fall upon its expulsion by boiling. Carbonate of lime and magnesia are deposited in the form of a white precipitate. Carbonate of iron occasions the separation of a rusty brown ferruginous powder, and the water is blackened by a few drops of tincture of galls.

e. Mr. R. Phillips, in his analysis of Bath waters, has shown that the delicacy of galls, as a test for iron, is curiously affected by the presence of certain salts: if the iron be in the state of protoxide, its detection is facilitated by salts with a base of lime, and by alcalis; if in the state of peroxide, lime prevents the action of the test. This is well shown by dissolving a *very* minute portion of protosulphate of iron in a glass of distilled water, and adding a drop of tincture of galls, which occasions no immediate discoloration; but a drop of lime-water, or other alcali, instantly renders the presence of iron evident; so that the quantity of iron present in a water cannot be correctly judged of by the degree of precipitation occasioned in it by tincture of galls.

f. Ferro-cyanate of potassa is also a good test to show minute quantities of iron in water, by the blue precipitate which it occasions; its action is aided by previously adding two or three drops of nitric acid to the water; but it is an equivocal test compared with galls.

g. The presence of muriatic salts and of chlorides, is indicated by a white cloud on adding sulphate of silver.

h. The sulphates, when present in water, afford a white precipitate on the addition of nitrate of baryta, which is insoluble in nitric acid.

i. Lime is recognised by a white cloud on dropping oxalate of ammonia into the water. A portion of the precipitate collected upon leaf platinum, and heated before the blow-pipe, may be burned into quicklime.

k. Magnesia is rendered evident by adding carbonate of ammonia which throws down the lime, and subsequently pouring in phosphate of soda, which, when magnesia is present, carries a portion of it down in the form of a granular precipitate of ammoniaco-magnesian phosphate.

Such are the readiest means of recognising the presence of the various substances that commonly occur, by the action of re-agents or tests; and, having gained such general information, we next proceed to the analysis of the water, in order to ascertain the relative proportions of the gaseous and saline ingredients which it holds dissolved.

SECTION III. *Analysis of Mineral Waters.*

1507. v. To ascertain the relative proportions of the gaseous contents of water with perfect accuracy, is a very difficult undertaking, and rarely necessary; the following method is sufficiently precise in all ordinary cases of analysis. Provide a Florence flask capable of holding rather more than a measured wine-pint, which quantity of the water under examination is to be introduced into it, and a cork carefully fitted to its neck, through a perforation in which is inserted a glass tube one-eighth inch diameter, rising perpendicularly about 18 inches, and then bent so as to pass conveniently under the shelf of the mercurio-pneumatic apparatus. (Where a sufficiency of mercury cannot be procured, warm water may be substituted, if only carbonic acid be present, and it may be absorbed by transferring the jar containing it to a solution of potassa.) The flask should be placed over an argand lamp, and heat gradually applied till the water fully boils. The gas evolved is to be collected in the usual way, in a graduated jar over quicksilver, and submitted to the following examination :—

vi. Throw up a small quantity of solution of potassa, which, if carbonic acid be present, will absorb it, and the quantity will be shown by the diminution of bulk.

vii. Introduce the remaining air, or a portion of it, into a small bent tube, containing a bit of phosphorus ; heat it so as to kindle the phosphorus, and note the diminution of bulk when cold. It is proportional to the oxygen present, and, if equal to one-fifth of the whole bulk, the gas may be regarded as atmospheric air*.

viii. If sulphuretted hydrogen be present it may be separated by strong alcoholic solution of iodine, which rapidly absorbs it, and scarcely takes up more than its own volume of carbonic acid gas. Chlorine, added

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* In separating oxygen a solution of nitric oxide in protosulphate of iron may sometimes conveniently be employed, but it does not give so accurate a result as the action of phosphorus.

to a mixture of sulphuretted hydrogen and carbonic acid, will also produce the absorption of the former if a little water be present; but it cannot be conveniently used over mercury.

ix. During the ebullition it not unfrequently happens that a precipitation ensues, indicating that the substances thrown down were dissolved by carbonic acid; and in that case they should be separated upon a filter A, after which the remaining water may be evaporated to dryness in a glazed porcelain basin; the dry residue transferred to a silver capsule, and perfectly desiccated at a temperature not exceeding 500°. B.

The precipitate A may consist of carbonate of lime, of carbonate of magnesia, or of oxide of iron; or it may be a mixture of the three; dissolve it in dilute muriatic acid, and add oxalic acid which throws down oxalate of lime; separate this by filtration, and saturate the filtrated portion with carbonate of ammonia, which precipitates the peroxide of iron, and having removed this, evaporate the residuary mixture, and expose the dry salt to a red heat in a small platinum capsule; the magnesia, if any were present, will remain; if not there will be no residue, for the oxalic acid and muriate of ammonia will be destroyed and volatilized.

100 parts of oxalate of lime indicate 77 of carbonate of lime.

100 parts of red oxide of iron indicate 90 of black oxide, or 143 of carbonate of iron. When carbonic acid holds iron in solution, the metal is in the state of protoxide, and if air be excluded, it requires long boiling to decompose it; for the same reason, if the

water be exposed, under the exhausted receiver of the air-pump, it does not readily become brown, as is the case when it is exposed to air ; a drop or two of nitric acid facilitates the deposition of the red oxide.

100 parts of pure magnesia are equivalent to 213 of carbonate of magnesia.

x. The dry residue B, is to be digested in six or eight parts of boiling alcohol, specific gravity 0.817, which will take up muriate of magnesia, and in some rare cases (where no sulphates are present) muriate of lime. Filter off the alcoholic solution, and wash the residue C with a little fresh alcohol, which add to the former, and evaporate to dryness D. The dry mass D, exposed for some time to a heat of 500°, is generally pure muriate of magnesia ; if it contain muriate of lime, the latter earth may be separated by solution of oxalic acid, in the state of oxalate of lime.

I have found it, in some cases, convenient to convert the muriates of lime and magnesia into sulphates, by pouring upon them excess of sulphuric acid, evaporating to dryness, and heating the dry mass red hot. The sulphate of magnesia may then be almost completely separated from the sulphate of lime, by a small quantity of cold water ; or a saturated solution of sulphate of lime may be used, which takes up the sulphate of magnesia, and, of course, leaves the sulphate of lime.

The alcohol will also take up a very minute portion of sea-salt, which, however, is too small to require estimation.

xi. The residue C, insoluble in alcohol, may contain sea-salt, sulphate of soda, sulphate of magnesia, and sulphate of lime ; digest it in ten parts of boiling distilled water, which, when cold, will have taken up every thing but sulphate of lime, of which an inappretiable portion only will have been dissolved; separate the solution into two equal portions, *a* and *b*.

To *a* add nitrate of silver, and wash and dry the precipitate, which is chloride of silver, and of which 100 parts indicate 41 of sea-salt.

To *b* add acetate of baryta as long as it occasions a precipitate, which is sulphate of baryta, and which is to be separated, dried and weighed. 100 grains are equivalent to 60.5 of sulphate of soda, and to 51 of sulphate of magnesia.

In order to ascertain the quantity of magnesia present, and consequently the quantity of sulphuric acid belonging to it, evaporate the liquid filtered off the barytic precipitate E to dryness; it will contain sea-salt, acetate of soda, acetate of magnesia, and, probably, a portion of the added acetate of baryta; ignite the dry mass, and wash it to separate the sea-salt and soda; magnesia and carbonate of baryta will remain insoluble, upon which pour dilute sulphuric acid; digest, filter, and evaporate the clear liquor to dryness; it is sulphate of magnesia, equivalent of course to the original portion of the salt; deduct the sulphuric acid contained in it from the whole in the precipitate E, and the remainder will give the quantity united to the soda.

xii. To estimate the quantity of sulphate of lime in the water, the residue of the evaporation of one pint may be washed with cold saturated solution of sulphate of lime, which will dissolve every thing but that sulphate, and which may thus be obtained and weighed; or, add oxalate of ammonia to a given quantity of the boiled and filtered water, collect the precipitate, and dry it at a heat of 500°. 100 grains of this oxalate indicate 104 of dry sulphate of lime.

xiii. Such are the general components of mineral waters, and the means of ascertaining their relative quantities. Let us suppose the following results have been obtained, with a view to illustrate the mode of drawing up the analysis. By the process v, twelve cubical inches of gas have been expelled during the ebullition of a pint of water. The exposure to solution of potassa has occasioned a diminution of eleven cubical inches, which, it having been previously ascertained that no sulphuretted hydrogen was present, may be considered as carbonic acid. The remaining gas thrown up into a tube containing a portion of phosphorus, and heated, suffers scarcely any diminution, and the phosphorus does not burn: hence it may be regarded as nitrogen. The gaseous contents, therefore, of the water under examination are, in the wine-pint—

Carbonic acid	11 cubic inches.
Nitrogen	1 ditto*.

If sulphuretted hydrogen be present, it is best to have recourse to a separate operation to estimate its quantity: for this purpose collect the gas as before, and throw up into it a small quantity of alcoholic

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* Of this nitrogen, a small portion will probably have been derived from the air in the tube connecting the flask with the pneumatic apparatus; a little practice soon enables the operator to ascertain when it has been expelled; or it may be received entire, and afterwards deducted from the whole produce.

solution of iodine. The absorption denotes the quantity of the gas. (viii.)

xiv. The next step of the operation relates to the examination of the precipitate deposited during ebullition, (ix. A.) Let us suppose the weight of oxalate of lime to be 3 grains, of oxide of iron 1.5 grain, and of magnesia 1 grain; then the above data give

	Grains.
Carbonate of lime	2.2
Carbonate of iron	2.4
Carbonate of magnesia	2.1

xv. The alcoholic solution (x.) may be diluted with water and tested by oxalic acid for lime; if absent, evaporate to dryness as directed. Let us suppose the residue to be

Muriate of magnesia	5 grains.

If the quantity of muriate of magnesia be considerable, greater accuracy is ensured by converting it into sulphate, which is done by placing it in a capsule of platinum, pouring upon it sulphuric acid, evaporating to dryness, and heating the dry mass to dull redness. 100 grains of this dry sulphate of magnesia indicate 94 of muriate of magnesia; hence the water under examination would have given 5.35 grains = 5 grains of muriate.

If the alcoholic solution contain muriate of lime, that earth must be previously separated by oxalic acid; and 100 parts of oxalate of lime are equivalent to 85 of dry muriate of lime.

xvi. The aqueous solution of the residue (c xi.) being divided into two portions, let us suppose the portion *a* xi. to afford 8.5 of chloride of silver, which indicates of sea-salt 3.5 grains = 7 grains in the pint.

xvii. Let us assume, that the precipitate of sulphate of baryta *b* xi. weighs 15 grains, indicating of

Sulphuric acid............	5.1	grains.

The process directed in xi. furnishes of

Sulphate of magnesia	3.75	grains,

which contain 2.5 grains of sulphuric acid, and which deducted from 5.1 grains leave 2.6 grains, which are adequate to the formation of

Sulphate of soda.........	4.65	grains.

So that the pint (the water having been divided into two equal portions) would contain of

Sulphate of magnesia 3.75 × 2 = 7.5 grains.
Sulphate of soda.... 4.65 × 2 = 9.3 grains.

xviii. The addition of oxalate of ammonia, or oxalic acid, to a pint of the boiled water (xii.) furnishes a precipitate of 4.7 grains of oxalate of lime, indicating of

Sulphate of lime............	5	grains.

xix. To give a general view, therefore, of the components of the mineral water which has thus been examined, we should place them as follows:—

One wine pint contains

	Cubic Inches.
Carbonic acid	11
Nitrogen	1
Gaseous contents	12

	Grains.
Carbonate of lime..................	2.20
Carbonate of iron..................	2.40
Carbonate of magnesia.............	2.10
Muriate of magnesia..............	5.00
Sea salt	7.00
Sulphate of magnesia	7.50
Sulphate of soda	9.30
Sulphate of lime	5.
Aggregate weight of solid contents	40.50

xx. Besides the substances now enumerated, and which may be considered as the most frequently occurring ingredients in mineral waters, there are others occasionally present, of which the following is an enumeration, with the best methods of detecting them:

a. Carbonate of soda is known to exist in water, when, after having been boiled down to half its bulk, and, if necessary, filtered, it reddens tumeric paper, and restores the blue of litmus reddened by vinegar; it also affords an effervescent precipitate with nitrate of baryta, soluble in dilute nitric acid. This carbonate is incompatible with the soluble salts of lime.

Muriate of lime may also be used to detect the alcaline carbonates, with which it affords a precipitate of carbonate of lime. Carbonate of soda is distinguished from that of potassa, by the latter affording a precipitate in neutral muriate of platinum, which the former does not. Carbonate of ammonia is obviously discoverable by its smell, when acted on by caustic fixed alcali or lime.

b. Silica is detected by evaporating the water to dryness, and boiling the residue in dilute muriatic acid. The silica, if present, remains as a white powder not altered by a red heat, but instantly fusing with a particle of carbonate of soda.

c. Boracic acid and borax have been found in certain lakes in India, and in some parts of Italy. To detect boracic acid, evaporate to one-eighth the original bulk of the water, and add carbonate of soda as long as it occasions any precipitate; boil and filter. The filtered liquor will contain borate of soda, with some other salts of the same basis; evaporate to dryness in a platinum crucible, and digest the residue in three or four parts of sulphuric acid, diluted with its bulk of water. If boracic acid be present, it will separate in micaceous crystals.

d. Alumina has been found in a few mineral waters in the state of a sulphate. It may be separated by the following process: Evaporate to dryness, digest in alcohol, and re-dissolve the residue in eight parts of water; filter and add oxalic acid, which throws down lime, and which being separated, leaves magnesia and alumina in solution. Carbonate of ammonia throws down the alumina and leaves the magnesia.

Pure ammonia throws down both alumina and magnesia. These earths may be separated by solution of potassa, which dissolves the former but not the latter.

e. Manganese is sometimes found in water, but only in very small proportion, so as not to amount to more than a trace. Dr. Scudamore found a trace of manganese in the waters of Tunbridge Wells, and it has never been discovered in larger proportion.

f. It has been said that certain nitrates are occasionally present in water, but such solutions can scarcely be called *mineral waters.* If nitrate of lime be present, it will be taken up from the residue of evaporation by alcohol, and may be decomposed by carbonate of potassa, so as to afford carbonate of lime and crystals of nitre.

g. It sometimes happens that water contains lead, which may be detected by evaporation to one-eighth its bulk, adding a few drops of nitric acid, and then hydriodate of potassa, which gives a yellow insoluble precipitate; and hydrosulphuret of ammonia, which forms a deep brown or black cloud. These precipitates may be reduced by heating them before the blowpipe upon charcoal, mixed with a little black flux.

h. If vegetable or animal matter be contained in water, it gives it a brown colour, especially when evaporated. It may be destroyed in the dry residue by igniting it with a small addition of nitrate of ammonia.

The following analyses of mineral waters may be advantageously consulted by the student, as containing a variety of useful details, which are necessarily omitted in the above observations:—*Analysis of the Hot Springs at Bath,* by RICHARD PHILLIPS, Esq. *Analysis of the Brighton Chalybeate,* by Dr. MARCET. *Analysis of the Tunbridge Wells Waters,* by Dr. SCUDAMORE. Mr. CHILDREN'S *Translation of* THENARD'S *Essay on Chemical Analysis,* chap. vi.

1508. TABULAR VIEW OF THE COMPOSITION OF MINERAL WATERS.

One Pint (Wine Measure) contains the following Ingredients:

	WATERS	GASES			CARBONATES			SULPHATES			MURIATES			Oxide of Iron	Silica	Temperature	Total of Saline Contents	AUTHORITY
		Nitrogen C. I.	Carbonic Acid, C. I.	Sulphuretted Hydrogen C. I.	Carbonate of Soda, grains	Carbonate of Magnesia, grains	Carbonate of Lime, grains	Sulphate of Soda, grains	Sulphate of Magnesia, grains	Sulphate of Lime, grains	Muriate of Soda, grains	Muriate of Magnesia, grains	Muriate of Lime					
CARBONATED	Seltzer	......	17.	......	4.	5.	3.	......	......	......	17.	......	......	....	....	Cold	29.	Bergman.
	Pyrmont	......	26.	......	......	10.	4.5	......	5.5	8.5	1.5	......	......	0.6	....	do.	30.6	Ditto.
	Spa	......	13.	......	1.5	4.5	1.5	......	......	......	0.2	......	......	0.6	....	do.	8.3	Ditto.
	Carlsbad	......	5.	......	5.	......	1.5	8.5	......	......	4.5	......	......	a trace	0.3	165°	19.8	Klaproth.
	Pouges	......	30.	......	10.	1.2	12.	......	......	......	2.2	......	......	2.5	0.5	Cold	28.4	Hassenfratz.
	Saint Parize	......	22.	......	......	0.5	11.5	......	......	13	......	......	......	....	....	do.	25.	Ditto.
SULPHUREOUS	Harrogate	0.8	1.	2.3	......	0.7	2.5	......	1.3	......	77.	11.	1.5	....	....	do.	94.	Garnet.
	Moffatt	0.5	0.6	1.2	......	......	......	......	......	......	4.5	......	......	....	....	do.	4.5	Ditto.
	Aix-la-Chapelle	......	......	5.5	12.	......	4.2	......	......	......	5.	......	......	....	....	143°	21.2	Bergman.
	Cheltenham Sulphur Spring	......	1.5	2.5	......	......	......	23.5	5.	1.2	35.	......	......	0.3	....	Cold	65.	Parkes & Brande.
SALINE	Seidlitz	......	......	......	......	2.5	0.8	......	180.	5.	......	4.5	......	....	....	do.	192.8	Bergman.
	Cheltenham pure Saline	......	......	......	......	......	......	15	11.	4.5	50.	......	......	....	....	do.	80 5	Parkes & Brande.
	Bristol	......	3.5	......	......	......	1.5	1.5	......	1.5	0.5	1.	......	....	....	74°	6.	Carrick.
	Buxton	0.2	......	......	......	......	1.3	......	......	0.3	0.2	......	......	0.03	....	82°	1.83	Pearson.
	Bath	......	1.2	......	......	......	0.8	1.5	......	9.	3.3	......	......	a trace	0.2	116°	14.6	Phillips.
	Scarborough	......	......	......	......	......	a trace	20.	......	9.	......	......	......	ditto	....	Cold	2.9	Saunders.
	Barege	......	......	uncertain	2.5	......	ditto	......	......	a trace	0.5	......	......	....	....	120	3.	Ditto.
	Plombieres	......	......	......	2.2	......	0.3	2.3	......	......	1.5	......	......	....	0.3	?	66.	Vauquelin.
	Kilburn	......	3.5	8.5?	......	0.5	1.	12.	37.	5.5	2.5	5.5	0.2	a trace	....	Cold	64.2	Schmeisser.
	Leamington New Bath	0.4	a trace	a trace	......	......	......	19.	......	14.	53.	1.5	......	0.8	....	do.	88.3	Lambe.
	Leamington Old Bath	0.3	......	ditto	......	......	......	7.5	7.	18.	41.	......	......	....	....	do.	73.5	Ditto.
CHALYBEATE	Tunbridge	0.59	1.	a trace of oxygen	......	......	0.03	......	......	0.17	0.30	0 03	0.05	0.28	....	do.	0.56	Scudamore.
	Cheltenham Chalybeate	......	2.5	......	0.5	......	......	22.7	6.	2.5	41.3	......	......	0.8	....	do.	73.8	Parkes & Brande.
	Brighton	......	2.2	......	......	......	......	......	......	4.	3.	0.75	......	1.4	0.14	do.	9.29	Marcet.

APPENDIX,

CONTAINING

TABLES OF SPECIFIC GRAVITIES, EQUIVALENT NUMBERS,

&c. &c.

TABULAR VIEW of SPECIFIC GRAVITIES and EQUIVALENT NUMBERS of the METALS and their COMBINATIONS.

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
I. POTASSIUM	0.85	37.5		The following characters belong to the Salts of Potassium: they are all soluble in water, and afford no precipitates with pure or carbonated alcalis; they produce a precipitate in muriate of platinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by sulphuretted hydrogen, nor by ferrocyanate of potassa. Added to sulphate of alumina, they enable it to crystallize so as to form octoëdral alum.
—— protoxide, or dry potassa	2.5	45	37.5 P. + 7.5 oxygen.	
———— hydrate	1.7	53.5	45 Ox. Potassium + 8.5 water.	
—— peroxide		60	37.5 P. + 22.5 oxygen.	
—— chloride		71	37.5 P. + 33.5 C.	
—— chlorate		116	45 O. P. + 71 C.A.	
—— oxychlorate		131	45 O. P. + 86 oxych. a.	
—— iodide		155.25	37.5 P. + 117.75 I.	
—— hydriodate		163.75	45 O. P. + 118.75. H, A.	
—— iodate		200.2	45 O. P. + 155.2 iod. a.	
—— hydruret		385.2	37.5 P. + 1 Hydro.?	
—— hydrogen potassuretted				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
POTASSIUM. nitrate	1.99	95.5	45 O. P. + 50.5 N. A.	
———— sulphuret		52.5	37.5 P. + 15 S.	
———— hyposulphite		67.5	45 O.P. + 22.5 Hyp. S. A.	
———— sulphite		75	45 O. P. + 30 S. A.	
———— sulphate	2.4	82.5	45 O.P. + 37.5 S. A.	
———— bisulphate		120	45 O. P. + 75 S. A.	
———— ammonio-sulphate		136	45 O. P. + 75. S. A. + 16 A.	
———— phosphuret		48.5	37.5 P. + 11 Phos.	
———— hypophosphite ?				
———— phosphite		63.5	45 O. P. + 18.5 P. A.	
———— phosphate		71	45 O. P. + 26 P. A.	
———— subphosphate		116	90 O. P. + 26 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
POTASSIUM. biphosphate	....	97	45 O. P. + 52 P.A.	
——— carbonate	....	65.7	45 O. P. + 20.7 C. A.	
——— bicarbonate	2.01	86.4	45 O. P. + 41.4 C. A.	
——— cyanuret				
——— hydrocyanate				
——— borate	....	65	45 O. P. + 20 B.A.	
II. SODIUM	0.9	22		All the Salts of Soda are soluble in water; they are not precipitated by pure or carbonated alcalis, nor by hydrosulphuret of ammonia, nor ferrocyanate of potassa; nor do they produce any precipitate in solution of muriate of platinum. They do not convert sulphate of alumina into octoëdral alum.
——— 1. oxide	....	29.5	22 S. + 7.5 O.	
——— hydrated	....	38	29.5 O. S. + 8.5 W.	
——— peroxide	....	33-25	22 S. + 11.25 Ox.	
——— chloride	....	55.5	22 S. + 33.5 C.	
——— chlorate	....	100.5	29.5. O. S. + 71 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Sodium. oxychlorate		115.5	29.5 O. S. + 86 Oxy. C. A.	
—— iodide		139.75	22 S. + 117.75 I.	
—— iodate		184.75	29.5 O. S. + 155.25 O. A.	
—— hydriodate		148.25	29.5 O. S. + 118.75 H. A.	
—— nitrate	2.09	80	29.5 O. S. + 50.5 N. A.	
—— sulphuret		37	22 S. + 15 Sul.	
—— hyposulphite		52	29.5 O. S. + 22.5 Hyp. S. A.	
—— sulphite		59.5	29.5 O. S. + 30 S. A.	
—— sulphate		67	29.5 O. S. + 37.5 S. A.	
—— —— crystallized		152	67 S. S. + 85 Water.	
—— bisulphate		104.5	29.5 O. S. + 75 S. A.	
—— ammonio sulphate		120.5	29.5 O.S. + 75 S.A. + 16 Am.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SODIUM. phosphuret		33	22 S. + 11 P.	
——— phosphite		48	29.5 O. S. + 18.5 P. A.	
——— phosphate		55.5	29.5 O. S. + 26 P. A.	
——— biphosphate		81.5	29.5 O. S. + 52 P. A.	
——— ammonio-phosphate		97.5	29.5 O. S. + 52 P. A. + 16 Am.	
——— carbonate	1.35	50.2	29.5 O. S. + 20.7 C. A.	
——— bicarbonate		70.9	29.5 O. S. + 41.4 C. A.	
——— cyanuret				
——— hydrocyanate				
——— borate, or borax	1.74			
III. LITHIUM		9		Lithia is distinguished from potassa and soda, by its high saturating power, by the difficult solubility of its carbonate, by
——— oxide		16.5	9 L. + 7.5 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
LITHIUM. chloride	....	42.5	9 L. + 33.5 C.	the deliquescency and ready solubility of its chloride, and by the characters of its sulphate.
——— chlorate	....	87.5	16.5 O. L. + 71 chl. ac.	
——— nitrate	....	67	16.5 O. L. + 50.5 N. A.	
——— sulphate	....	54	16.5 O. L. + 37.5 S. A.	
——— phosphate	....	42.5	16.5 O. L. + 26 P. A.	
——— carbonate	....	37.2	16.5 O. L. + 20.7 C. A.	
IV. CALCIUM	....	19		The Salts of Lime furnish precipitates of carbonate of lime by the carbonated alcalis; they afford no precipitate with caustic ammonia. Oxalic acid, and oxalate of ammonia, produce precipitates of oxalate of lime, which, at a red heat, affords quicklime.
——— oxide, or lime	1,5	26.5	19 C. + 7.5 O.	
——— ——— hydrate	....	35	26.5 O. C. + 8.5 W.	
——— chloride	....	52.5	19 C. + 33.5 C.	
——— muriate	....	61	26.5 O. C. + 34.5 M. A.	
——— oxymuriate ?				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Calcium. chlorate		97.5	26.5 O. C. + 71 C. A.	
——— iodide		136.7	19 C. + 117.7 I.	
——— oxyiodate		181.75	26.5 O. C. + 155.25 O. A.	
——— hydriodate		145.2	26.5 O. C. + 118.7 H. A.	
——— nitrate	1.6	77	26.5 O. C. + 50.5 N. A.	
——— sulphuret		34	19 C. + 15 S.	
——— hyposulphite		49.5	26.5 O. L. + 22.5 hyp. S. A.	
——— sulphite		56.5	26.5 O. C. + 30 S. A.	
——— sulphate		64	26.5 O. C. + 37.5 S. A.	
——— crystallized		81	64 dry sulphate + 17 water	
——— phosphuret		30	19 C. + 11 P.	
——— phosphate		52.5	26.5 O. C. + 26 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
CALCIUM. biphosphate		78.5	26.5 O. C. + 52 P. A.	
—— carbonate	2.7	47.2	26.5 O. C. + 20.7 C. A.	
—— borate		46.5	26.5 O. C. + 20 B. A.	
—— fluoride	3.	34	19 C. + 15 Fluorine ?	
Hydrofluoric acid		16	15 Fluorine + 1 hydrogen	
Fluoboric gas		20.	15 F. + 5 B.	
	32.68	to hydrogen	23.71 to atmospheric air.	
V. BARIUM		65		The Soluble Barytic Salts furnish white precipitates of carbonate of baryta, by the alcaline carbonates. Sulphuric acid and the soluble sulphates occasion white precipitates of sulphate of baryta in the solutions of the earth. They are poisonous, and tinge flame yellow.
—— oxide		72.5	65 B. + 7.5 O,	
—— —— hydrate		81	72.5 O. B. + 8.5 W.	
—— chloride		98.5	65 B. + 33.5 C.	
—— chlorate		143.5	72.5 O. B. + 71 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
BARIUM. iodide	....	182.7	65 B. + 117.7 I.	
——— iodate	....	227.7	72.5 O. B + 155.2 I. A.	
——— hydriodate	....	191.2	72.5 O. B. + 118.7 H. A.	
——— nitrate	....	123	72.5 O. B. + 50.5 N. A.	
——— sulphuret	....	80	65 B. + 15 S.	
——— hyposulphite	....	95	72.5 O. B. + 22.5 hyp. S. A.	
——— sulphite	....	102.5	72.5 O. B. + 30 S. A.	
——— sulphate	4.4	110	72.5 O. B. + 37.5 S. A.	
——— phosphuret	....	76	65 B. + 11 P.	
——— phosphite	....	91	72.5 O. B. + 18. 5 P. A.	
——— phosphate	1.28	98.5	72.5 O. B. + 26 P. A.	
——— carbonate	4.2	93.2	72.5 O. B. + 20.7 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
BARIUM. borate	....	92.5	72.5 O. B. + 20. B. A.	
VI. STRONTIUM	....	44.5		The Salts of Strontium furnish white precipitates with the alcaline carbonates, and with sulphuric acid and sulphates; they tinge flame of a fine red; they are not poisonous. They are decomposed by baryta, which has a stronger attraction for acids than strontia; they are more soluble than barytic salts, but pure strontia is less soluble than baryta.
—— oxide	....	52	44.5 S. + 7.5 O.	
——— hydrate	....	60.5	52 O. S. + 8.5 W.	
—— chloride	....	78	44.5 S. + 33.5 C.	
—— chlorate	....	123	52 O. S. + 71 C. A.	
—— muriate	....	86.5	52 O. S. + 34.5 M. A.	
—— iodide	....	162.2	44.5 S. + 117.7 I.	
—— iodate	....	207.2	52 O. S. + 155.2 I. A.	
—— nitrate	....	102.5	52 O. S. + 50.5 N. A.	
—— sulphuret	....	59.5	44.5 S. + 15 Sul.	
—— hyposulphite	....	74.5	52 O. S. + 22.5 Hyp. S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
STRONTIUM. sulphite	....	82	52 O. S. + 30 S. A.	
——— sulphate	3.9	89.5	52 O. S. + 37.5 S. A.	
——— phosphate		78	52 O. S. + 26 P. A.	
——— carbonate	3.6	72.7	52 O. S. + 20.7 C. A.	
——— borate	....	72	52 O. S. + 20 B. A.	
VII. MAGNESIUM	....	11		The salts of magnesia are decomposed by solution of potassa, and by its carbonate; the precipitate does not re-dissolve in excess of the alcalis, but readily dissolves in excess of sulphuric acid. The salts of magnesia are not precipitated by a solution of bicarbonate of potassa (cold), nor by carbonate of ammonia; but if heat be applied, carbonic acid escapes, and the earth is
——— oxide	2.3	18.5	11 M. + 7.5 O.	
——— hydrate	....	27	18.5 O. M. + 8.5 W.	
——— chloride	....	44.5	11 M. + 33.5 C.	
——— muriate	....	53	18.5 O. M. + 34.5 M. A.	
——— chlorate	....	89.5	18.5 O. M. + 71 C. A.	
——— hydriodate	....	137.2	18.5 O. M. + 118.7 H. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MAGNESIUM. nitrate	....	69	18.5 O. M. + 50.5 N. A.	precipitated in the state of carbonate. The salts of magnesia are only partially decomposed by ammonia, which forms triple salts with the earth and acid. Oxalate of ammonia does not precipitate magnesia.
——— ammonio-nitrate	....	135.5	18.5 O.M. + 101 N. A. + 16 Am.	
——— sulphuret				
——— hyposulphite	....	41	18.5 O. M. + 22 5 hypo. S. A.	
——— sulphite	....	48.5	18.5 O. M. + 30 S. A.	
——— sulphate	1.66	56	18.5 O M. + 37.5 S. A.	
——— ——— crystallized	....	115.5	56 S. M. + 59.5 water	
——— ammonio-sulphate	....	109.5	18.5 O. M. + 75 S. A. + 16 amm.	
——— potassa-sulphate	....	138.5	18.5 O.M. + 75 S.A. + 45 potassa	
——— phosphate	....	44.5	18.5 O. M. + 26 P. A.	
——— bi-phosphate	....	70.5	18.5 O. M. + 52 P. A.	
——— ammonio-phosphate	....	86.5	18.5 O. M. + 52 P. A. + 16 amm.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MAGNESIUM. carbonate	....	39.2	18.5 O. M. + 20.7 C. A.	
——— bicarbonate	....	59.9	18.5 O. M. + 41.4 C. A.	
——— borate	....	38.5	18.5 O. M. + 20 B. A.	
VIII. MANGANESE	6.85	28.5		The Salts of Manganese are not precipitated by hydriodic acid. They furnish white precipitates with the alcalis, which blacken by exposure to air. They are precipitated white by ferrocyanate of potassa, and yellow by hydrosulphuret of ammonia.
——— 1. oxide	....	36	28.5 M. + 7.5 O.	
——— 2. oxide	....	39.7	28.5 M. + 11.25 O.	
——— peroxide	....	43.5	28.5 M. + 15 O.	
——— chloride	....	62	28.5 M. + 33.5 C.	
——— nitrate	....	86.5	36 O. M. + 50.5 N. A.	
——— sulphuret				
——— hyposulphite	....	58.5	36 O. M. + 22.5 hyp. S. A.	
——— sulphate	....	73.5	36 O. M. + 37.5 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MANGANESE. red sulphate?				
——— ——— phosphuret	....	39.5	28.5 M. + 11 P.	
——— ——— phosphate	....	62	36 O. M. + 26 P. A.	
——— ——— carbonate	....	56.7	36 O. M. + 20.7 C. A.	
IX. IRON	7.78	26		The Solutions of Iron are known by affording a purple or black precipitate to infusion of galls, which is an extremely delicate test of the presence of the metal, provided any earthy or alcaline salt be present. They give no precipitate with hydriodic acid.
—— 1. oxide	....	33.5	26 I. + 7.5 O.	
—— 2. oxide	....	37.75	26 I. + 11.75 O.	
—— 1. chloride	....	59.5	26 I. + 33.5 C.	
—— 2. chloride	....	76.25	26 I. + 50.25 C.	
—— protomuriate	....	68	33.5 O. I. + 34.5 M. A.	
—— permuriate	....	89.2	37.5 O. I. + 51.7 M. A.	
—— chlorate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Iron. iodide		143.7	26 I. + 117.7 Iod.	The pure salts containing the black oxide give a white or very pale blue precipitate with ferrocyanate of potassa; while those containing the brown oxide furnish a dark blue precipitate, (Prussian blue).
—— protonitrate		84	33.5 O. I. + 50.5 N. A.	
—— pernitrate		113.2	37.5 O. I. + 75.7 N. A.	
—— sulphuret		41	26 I. + 15 S.	
—— bisulphuret		56	26 I. + 30 S.	
—— hyposulphite?				
—— protosulphate		71	33.5 O. I. + 37.5 S. A.	
—— —— crystallized.	1.83	130.5	71 dry + 59.5 W. (7 props.)	
—— persulphate?				
—— hydrosulphuret				
—— phosphuret		37	26 I. + 11 P.	
—— protophosphate		59.5	33.5 O. I. + 26 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Iron. perphosphate ?				
—— carburet				
—— carbonate		54.2	33.5 O. I. + 20.7 C. A.	
X. Zinc	7	33		The Solutions of Zinc are not precipitated by hydriodic acid. Potassa, soda, and ammonia, form white precipitates redissoluble in excess either of acid or alcali. Hydrosulphuret of ammonia produces a yellowish white precipitate ; and the soluble phosphates, borates, and carbonates, all form white precipitates.
—— oxide		40.5	33 Z. + 7.5 O.	
—— chloride		66.5	33 Z. + 33.5 C.	
—— chlorate		111.5	40.5 O. Z. + 71 C.A.	
—— muriate		75	40.5 O. Z. + 34,5 M. A.	
—— iodide		150.7	33 Z + 117.7 I.	
—— iodate		195.7	40.5 O. Z. + 155.2 I. A.	
—— hydriodate		159.2	40.5 O. Z. + 118.7 H. A.	
—— nitrate		91	40.5 O. Z. + 50.5 N. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
ZINC. sulphuret		48	33 Z. + 15 S.	
—— hyposulphite		63	40.5 O. Z. + 22.5 Hyp. S. A.	
—— sulphite		70.5	40.5 O. Z. + 30 S. A.	
—— sulphate	1.9	78	40.5 O. Z. + 37.5 S. A.	
—— —— crystallized		137.5	78.5 Z. + 59.5 Water	
— hydrosulphuret				
—— phosphuret		44	33 Z. + 11 P.	
—— phosphate		66.5	40.5 O. Z. + 26 P. A.	
—— carbonate		61.2	40.5 O. Z. + 20,7 C. A.	
—— borate		60.5	40.5 O. Z. + 20 B. A.	
XI. TIN	7.30	55.5		The Hydriodic Acid affords a fine orange precipitate with solution of muriates of tin, pro-
—— 1. oxide		63	55.5 T. + 7.5 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
TIN. 2. oxide	....	70.5	55.5 T. + 15 O.	vided there be no excess of acid. Hydrosulphuret of ammonia produces a precipitate of a deep orange colour.
—— 1. chloride	....	89	55.5 T. + 33.5 O.	
—— 2. chloride	....	122.5	55.5 T. + 67 C.	
—— protomuriate	....	97.5	63 O. T. + 34.5 M. A.	
—— permuriate	....	139.5	70.5 O. T. + 69 M. A.	
—— iodide	....	172-7	55 T. + 117.7 I.	
—— nitrate	....	113.5	63 O. T. + 50.5 N A.	
—— sulphuret	....	70.5	55·5 T. + 15 S.	
—— bisulphuret	....	85.5	55.5 T. + 30 S.	
—— sulphate	....	100.5	63 O. T. + 37.5 S. A.	
—— hydrosulphuret				
—— phosphuret	....	65	55 T. + 10 P.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity.	Equivalent Number.	COMPOSITION	REMARKS.
XII. Cadmium	8.63	52.5		Cadmium is readily soluble in muriatic acid. Its neutral solutions are precipitated yellow by sulphuretted hydrogen, and furnish a metallic precipitate upon immersed zinc. The annexed equivalent of Cadmium is deduced from Stromeyer's Analyses (1419.)
——— oxide	....	60	52.5 C. + 7.5 O.	
——— chloride	....	86	52.5 C. + 33.5 Chlor.	
——— iodide	....	170.2	52.5 + 117.7 Iod.	
——— nitrate	....	110.5	60 O. C. + 50.5 N. A.	
——— sulphuret	....	67.5	52,5 C. + 15 S.	
——— sulphate	....	97.5	60 O. C. + 37.5 S. A.	
——— phosphuret	....	63.5	52.5 C. + 11 P.	
——— phosphate	....	86	60 O. C. + 26 P. A.	
——— carbonate	....	80.7	60 O. C. + 20.7 C. A.	
XIII. Copper	8.8	60		The salts of this metal containing the peroxide, are distinguished by their blue and
——— 1. oxide	....	67.5	60 C. + 7.5 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity.	Equivalent Number	COMPOSITION	REMARKS.
COPPER. 2. oxide	....	75	60 C. + 15 O.	green colours ; their solutions afford blue precipitates of hydrated oxide with the alcalis, and these redissolve in excess of ammonia, producing a deep blue solution. A plate of iron precipitates metallic copper ; ferrocyanate of potassa affords a fine brown precipitate ; hydrosulphuret of ammonia, one of a dirty brown ; hydriodic acid produces an insoluble iodide of an ash grey colour. The salts of copper containing the protoxide have hitherto been but imperfectly described.
—— 1. chloride	....	93.5	60 C. + 33.5 C.	
—— 2. chloride	....	127	60 C. + 67 C.	
—— chlorate				
—— iodide	....	177.7	60 C. + 117.7 I.	
—— sub-permuriate ?	....	184.5	75 O. C. + 34.5 M. A.	
—— permuriate	....	144	75 O. C. + 69 M. A.	
—— nitrate	2.17	176	75 O. C. + 101 N. A.	
—— ammoniuret				
—— sulphuret	....	75	60 C. + 15 S.	
—— bisulphuret	....	90	60 C. + 30 S.	
—— per-hyposulphite	....	97.5	75 O. C. + 22.5 Hyp. S. A.	

Metals and their Combinations (continued.)				
SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
COPPER. persulphite	....	105	75 O. C. + 30 S. A.	
——— potassa persulphite	....	180	75 O. C. + 60 S. A. + 45. Pot.	
——— persulphate (dry)..........	....	150	75 O. C. + 75 S. A.	
——— persulphate crystallized	2.19	235	75 O. C. + 75 S. A. + 85 water.	
——— subpersulphate				
——— hydrosulphuret				
——— phosphuret	....	71	60 C. + 11 P.	
——— protophosphate............	....	93.5	67.5 O. C. + 26 P. A.	
——— perphosphate	....	125	75 O. C. + 50 P. A.	
——— percarbonate..............	....	95.7	75 O. C. + 20.7 C. A.	
——— perborate	....	95	75 O. C. + 20 B. A.	
XIV. LEAD	11.35	97		

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
LEAD. 1. oxide	....	104.5	97 L. + 7.5 O.	The soluble Salts of Lead furnish colourless solutions of a sweetish taste, precipitated white by sulphate and ferrocyanate of potassa, and by infusion of galls; brownish black by sulphuretted hydrogen; and brown by hydrosulphuret of ammonia. Hydriodic acid affords a fine yellow precipitate of iodide of lead. The alcalis produce white precipitates, *easily soluble* in excess of potassa or soda, but *insoluble* in excess of ammonia. Zinc precipitates metallic lead. The insoluble salts of lead treated by the blow-pipe on charcoal, afford a globule of lead.
—— 2. oxide	....	108.25	97 L. + 11.25 O.	
—— 3. oxide	....	112	97 L. + 15 O.	
—— chloride	....	130.5	97 L. + 33.5 C.	
—— chlorate	....	175.5	104.5 O. L. + 71 C. A.	
—— iodide	....	214.7	97 L. + 117.7 I.	
—— iodate	....	259.7	104.5 O. L. + 155.2 I. A.	
—— nitrate	....	155	104.5 O. L. + 50.5 N. A.	
—— subnitrate	....	259.5	209 O. L. + 50.5 N. A.	
—— sulphuret	....	112	97 L. + 15 S.	
—— sulphite	....	134.5	104.5 O. L. + 30 S. A.	
—— sulphate	....	142	104.5 O. L. + 37.5 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
LEAD. hydrosulphuret				
—— phosphuret	....	108	97 L. + 11 P.	
—— phosphite	....	122.5	104.5 O. L. + 18.5 Ps. A.	
—— phosphate	....	130.5	104.5 O. L. + 26 P. A.	
—— carbonate	....	125.2	104.5 O. L. + 20.7 C. A.	
XV. ANTIMONY	6.70	45		The protomuriate of antimony is precipitated white by water; the precipitate is a subsalt. Sulphuretted hydrogen, and hydrosulphuret of ammonia, give an orange precipitate, and a plate of iron or zinc throws down the metal in the form of a black powder.
——— 1. oxide	......	52.5	45 A. + 7.5 O.	
——— 2 oxide	....	60	45 A. + 15 O.	
——— chloride	....	78.5	45 A. + 33.5 C.	
——— iodide	....	162.7	45 A. + 117.7 I.	
——— muriate				
——— sulphuret	....	60	45 A. + 15 S.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent† Number	COMPOSITION	REMARKS
Antimony. protosulphate		90	52.5 O. A. + 37.5 S. A.	
——— hydrosulphuret				
——— phosphuret		56	45 A. + 11 P.	
——— phosphate		78.5	52.5 O. A. + 26 P. A.	
XVI. Bismuth	9.80	66.5		
——— oxide		74	66 5 B. + 7.5 O.	The Salts of Bismuth are precipitated white by water—brownish black by sulphuretted hydrogen—yellowish white by ferrocyanate of potassa, and hydriodic acid affords a deep brown iodide of bismuth.
——— chloride		100	66.5 B. + 33.5 C.	
——— iodide		184.2	66.5 B. + 117.7 I.	
——— nitrate		124.5	74 O. B. + 50.5 N. A.	
——— sulphuret		81.5	66,5 B. + 15 S.	
——— sulphate		111.5	74 O. B. + 37·5 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
COBALT	8	30.5		Nearly all the Salts of Cobalt are of a red colour, when in dilute solution, but green or blue when concentrated; potassa, soda, and ammonia, produce in them blue precipitates of hydrated oxide, which is soluble in excess of ammonia, producing a red solution. Hydrosulphuret of ammonia gives a black precipitate: Ferrocyanate of potassa a pale green. Carbonates, phosphates, and arseniates, produce red precipitates. Hydriodic acid does not precipitate the salts of cobalt.
——— 1. oxide		38	30.5C. + 7.5 O.	
——— 2. oxide		41.7	30.5 C. + 11.2 O.	
——— chloride		64	30.5 C. + 33.5 C.	
——— muriate		72.5	38 O. C. + 34.5 M. A.	
——— sulphuret		45.5	30.5 C. + 15 S.	
——— sulphate		75.5	38 O. C. + 37.5 S. A.	
——— sulphate crystallized		135	38 O. C. + 37.5 S. A. 59,5 Water.	
——— phosphuret		41.5	30.5 C. + 11 P.	
——— phosphate		64	38 O. C. + 26 P. A.	
——— carbonate		58.7	38 O. C. + 20.7 C. A.	
XVIII. URANIUM	9	60		

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
URANIUM 1. oxide	....	67.5	60 U. + 7.5 O.	Of the salts of Uranium the greater number are soluble, and of a greenish yellow colour; they form yellow precipitates with the alcalis, and afford a reddish yellow iodide with hydriodic acid. Ferrocyanate of potassa forms a precipitate of a rich brown colour, and hydrosulphuret of ammonia one nearly black.
——— 2. oxide	....	75	60 U. + 15 O.	
XIX. TITANIUM				The Salts of Titanium are colourless, and afford white precipitate swith the alcalis. Ferrocyanate of potassa gives a green precipitate, and infusion of galls a red one. Hydrosulphuret of ammonia gives a green precipitate.
XX. CERIUM	....	86.2		
——— 1. oxide	....	101.2	86.2 C. + 15 O.	
——— 2. oxide	....	108.5	86.2 C. + 22.5 O.	
XXI. TELLURIUM	61.0	36.5		
——— oxide	....	44	36.5 T. + 7.5 O.	
——— chloride	....	70	36.5 T. + 33.5 C.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
XXII. SELENIUM				
XXIII. ARSENIC	8.3	44		Hydriodic Acid produces a precipitate of white oxide of arsenic, when added to arsenite of potassa, and hydriodate of potassa is formed. Arsenite of potassa gives a white precipitate with hydrosulphuret of ammonia; a white precipitate soon becoming yellow and brown with nitrate of silver; a grey precipitate with protonitrate, and a white with pernitrate of mercury; a white with nitrate of lead; a pale green with nitrate of nickel; pale pink by nitrate of cobalt; apple green with nitrate of copper; white with the protomuriate and permuriate of tin; dingy green with the muriates of iron; white with sulphate of zinc; bright yellow with nitrate of uranium.
——— 1. oxide (arsenious acid)	3.7	59	44 A. + 15 O.	
——— 2. oxide (arsenic acid)		66.5	44 A. + 22.5 O.	
——— chloride		111	44 A. + 67 C.	
——— muriate?		128	59 O. A. + 69 M. A.	
——— iodide		398.1	44 A. + 353.1 I.	
——— hydruret				
——— arseniuretted hydrogen				
——— sulphuret		59	44 A. + 15 S.	
——— bisulphuret		74	44 A. + 30 S.	
——— sulphate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Arseniate of ammonia		82.5	66.5 A. A. + 16 A.	The Arseniate of Potassa produces a reddish precipitate in nitrate of silver; straw-coloured with nitrate, and yellow with pernitrate of mercury; white with nitrate of lead; pale green with nitrate of nickel; pale blue with nitrate of copper; pink with nitrate of cobalt; white with protomuriate of tin; no precipitate with permuriate of tin; pale sea-green with muriate and permuriate of iron; straw colour with nitrate of uranium; and white with sulphate of zinc.
——— potassa		111.5	66.5 A. A. + 45 P.	
Binarseniate of potassa		178	133 A. A. + 45 P.	
Arseniate of soda		96	66.5 A. A. + 29.5 O. S.	
——— lime		92.5	66.5 A. A. + 26 Lime.	
——— baryta		139	66.5 A. A. + 72.5 O. B.	
——— strontia		118.5	66.5 A. A. + 52 S.	
——— magnesia		85	66.5 A. A. + 18.5 M.	
——— manganese		102.5	65.5 A. A. + 36 O. M.	The compounds of the arsenic and arsenious acids are decomposed when heated with charcoal, and exhale an alliaceous smell.
Protarseniate of iron		100	66.5 A. A. + 33.5 O. I.	
Perarseniate of iron		137.5	99.75 A. A. + 37.75 O. I.	
Arseniate of zinc		107	66.5 A. A. + 40.5 O. Z.	
——— tin		129.5	66.5 A. A. + 63 O. T.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Protarseniate of copper	....	134	66.5 A. A. + 67.5 O. C.	
Perarseniate of copper	....	208	133 A. A. + 75 O. C.	
Arseniate of lead	....	171	66.5 A. A. + 104.5 O. L.	
——— bismuth............	....	140.5	66.5 A. A. + 74 O. B.	
——— cobalt..............	....	104.5	66.5 A. A. + 38 O. C.	
——— uranium ?				
XXIV. MOLYBDENUM	7·40	44		
——— 1. oxide	....	51.5	44 M. + 7.5 O.	
——— 2. oxide	....	59	44 M. + 15 O.	
——— 3. oxide (acid)	....	66·5	44 M. + 22·5 O.	
——— sulphuret.........	....	74	44 M. + 30 S.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Molybdate of ammonia..........	....	82.5	66.5 M. A. + 16 A.	
———— potassa	....	111.5	66.5 M. A. + 45 P.	
———— soda	....	96	66.5 M. A. + 29.5 S.	
———— lead...............	....	171	66.5 M. A. + 104.5 O. L.	
XXV. CHROMIUM....................	5.9	28.5		
———— 1. oxide	....	36	28.5 C. + 7.5 O.	Chromic Acid and Chromate of Soda produce insoluble precipitates in solutions of silver, mercury, lead, copper, iron, and uranium; the colours are crimson, red, yellow or orange, apple-green, brown, and yellow. No precipitate is formed in solutions of nickel, zinc, tin, cobalt, gold, or platinum.
———— 2. oxide (chromic acid)	....	43.5	28.5 C. + 15 O.	
Chromate of ammonia	....	59.5	43.5 C. A. + 16 A.	
———— potassa............	....	88.5	43.5 C. A. + 45 P.	
———— lime	....	70	43.5 C. A. + 26.5 L.	
———— baryta	....	116	43.5 C. A. + 72.5 B.	
———— iron	....	77	43.5 C. A. + 33.5 O. I.	

Metals and their Combinations (continued).

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Chromate of lead		148	43.5 C. A. + 104.5 O. L.	
XXVI. TUNGSTEN	17.5	90		
——— Tungstic acid		112.5	90 T. + 22.5 O.	
Tungstate of lime		139	112.5 T. A. + 26.5 L.	
——— manganese		148.5	112.5 T. A. + 36 O. M.	
XXVII. COLUMBIUM		139		
——— oxide (acid)		146.5	139 C. + 7.5 O.	
Columbate of potassa		191.5	146.5 C. A. + 45 P.	
XXVIII. NICKEL	8.5	28		The Salts of Nickel form green solutions, of a sweetish acrid flavour; ammonia gives green precipitates, redissoluble in excess of alcali, and forming triple
——— oxide		35.5	28 N. + 7.5 O	
——— hydrate		44	35.5 O. N. + 8.5 W.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
NICKEL. chloride		61.5	28 N. + 33.5 C.	salts. Ferrocyanate of potassa forms a greenish precipitate; hydrosulphuret of ammonia gives a black precipitate; hydriodic acid forms a pea-green iodide.
——— iodide		145.7	28 N. + 117.7 I.	
——— nitrate		86	35.5 O. N. + 50.5 N. A.	
——— ammoniuret				
——— sulphuret		43	28 N. + 15 S.	
——— sulphate (dry)		73	35.5 O. N. + 37.5 S. A.	
——— ——— crystallized		132.5	73 S. N. + 59.5 W.	
——— potassa-sulphate		155.5	35.5 O. N. + 75 S. A. + 45 P.	
——— ferro-sulphate		144	35.5 O.N. + 75 S.A. + 33.5 O.I.	
——— phosphuret		39	28 N. + 11 P.	
——— phosphate		61.5	35.5 O. N. + 26 P. A.	
——— carbonate		56.2	35.5 O. N. + 20.7 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
NICKEL. borate	....	55.5	35.5 O. N. + 20 B. A.	
——— ammonio-sulphate	....	126.5	35.5 O.N. + 75 S.A. + 16 amm.	
XXIX. MERCURY	13.50	190		The Mercurial Salts are volatilized by heat. They are precipitated yellowish by ferrocyanate of potassa; deep brown by hydrosulphuret of ammonia; and copper separates pure mercury. The salts with the protoxide, give black precipitates with the alcalis, and white with muriatic acid. The salts with the peroxide furnish to the fixed alcalis reddish precipitates, and white with ammonia. Hydriodic Acid gives a yellow precipitate in solutions of protoxide, and a red precipitate with the peroxide. These are the protiodide and periodide of mercury.
——— protoxide	....	197.5	190 M. + 7,5 O.	
——— peroxide	....	205	190 M. + 15 O.	
——— chloride	....	223.5	190 M. + 33.5 C.	
——— bichloride	....	257	190 M. + 67. C.	
——— muriate?				
——— chlorate	Chlorate of Mercury is yellow and insoluble. Perchlorate furnishes crystals.			
——— iodide	....	307.7	190 M. + 117.7 I.	
——— periodide	....	425.4	190 M. + 235.4	
——— hydriodate	....	316.2	197.5 O. M. + 118.7 H. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MERCURY. protonitrate		248	197.5 O. M. + 50.5 N. A.	Phosphoric Acid produces a white insoluble precipitate in nitrate of mercury, but no precipitate in the pernitrate.
——— pernitrate		306	205 O. M. + 101 N. A.	
——— subpernitrate		460.5	410 O. M. + 50.5 N. A.	
——— sulphuret		205	190 M. + 15 S.	
——— bisulphuret		220	190 M. + 30 S.	
——— sulphite?		227.5	197.5 O. M. + 30 S. A.	
——— protosulphate		235	197.5 O. M. + 37.5 S. A.	
——— persulphate		280	205 O. M. + 75 S. A.	
——— bipersulphate?				
——— subpersulphate		242.5	205 O. M. + 37.5 S. A.	
——— hydrosulphuret?				
——— phosphuret?				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MERCURY. protophosphate		223·5	197·5 OM. + 26 P. A.	
——— perphosphate		257	205 O. M. + 52 P. A.	
——— protocarbonate		218.2	197·5 O. M. + 20.7 C. A.	
——— percarbonate		246.4	205 O. M. + 41·4 C. A.	
——— cyanuret		238.8	190 M. + 48·8 C.	
——— protoborate		217.5	197.5 O. M. + 20 B. A.	
——— perborate		245	205 O. M. + 40 B.A.	
——— protoarseniate		264	197.5 O. M. + 66.5 A. A.	
——— perarseniate		338	205 O.M. + 133 A. A.	
——— chromate?				
——— tungstate?				
XXX. OSMIUM				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
XXXI. IRIDIUM	18			
XXXII. RHODIUM	106			
XXXIII. PALLADIUM	11			
XXXIV. SILVER	10.50	102.5		The salts of silver are reduced upon charcoal by the blow-pipe. The soluble salts are precipitated by the alcalis, which furnish dark olive precipitates; by sulphuretted hydrogen and hydrosulphuret of ammonia, nearly black; by infusion of galls, yellow brown; by ferrocyanate of potassa, white. Muriatic acid, and the muriates, give white precipitates of chloride of silver. Sulphate of iron, and a plate of copper, throw down metallic silver.
—— oxide		110	102.5 S. + 7.5 ox.	
—— chloride		136	102.5 S. + 33.5 C.	
—— chlorate	A detonating salt.			
—— iodide —— hydriodate	Hydriodic acid throws down iodide of silver from the nitrate, at first white, but becoming *very* soon yellow, then grey and blackish.			
—— nitrate		160.5	110 O. S. + 50.5 N. A.	
—— ammoniuret	Liquid ammonia easily dissolves the oxide of silver. When the solution is evaporated, a grey compound remains, which leaves metallic silver when heated. Sometimes it detonates.			

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SILVER. sulphuret	....	117,5	102,5 S. + 15 Sul.	
—— sulphite	forms a white and difficultly soluble salt.			
—— sulphate	....	147.5	110 O. S. + 37. 5 S. A.	
—— hydrosulphuret				
—— phosphuret	....	113.5	102.5 S. + 11 P.	
—— phosphate	....	136	110 O. S. + 26 P. A.	
—— carbonate	....	130.7	110 O. S. + 20.7 C. A.	
—— cyanuret	....	151.3	102.5 O. S. + 48.8 C.	
—— hydrocyanate				
—— borate	Boracic acid produces no precipitate in solutions of silver, but borate of soda throws down a white *borate of silver*.			
Arseniate of Silver	....	176.5	110 O. S. + 66.5 A. A.	
Molybdate ——	....	176.5	110 O. S. + 66.5 M. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SILVER. Chromate		153.5	110 O. S. + 43.5 C. A.	
—— Tungstate		222.5	110 O. S. + 112.5 T. A.	
XXXV. GOLD	19.30	97 ?		The salts of gold are yellow and soluble in water. Potassa and soda produce in them yellow precipitates. Sulphuretted hydrogen and hydrosulphuret of ammonia occasion black precipitates: phosphuretted hydrogen, a purple precipitate: a plate of tin or muriate of tin, a purple powder. Sulphate of iron separates minutely-divided metallic gold. Tincture of galls gives a brown precipitate. Ferrocyanate of potassa occasions no precipitate.
—— peroxide		104.5 ?	97 G. + 7.5 ox.	
—— chloride		130.5 ?	97 G. + 33.5 C.	
—— muriate		139 ?	104.5 ox. G. + 34.5 M. A.	
—— chlorate				
—— iodide	Hydriodic acid produces an insoluble yellow precipitate in dilute muriate of gold, which is the iodide of gold. Heat separates the iodine.			
—— hydriodate				
—— nitrate		155 ?	104.5 ox. G. + 50.5 N. A.	
—— sulphuret		127 ?	97 G. + 30 S.	
—— sulphite	Sulphurous acid produces a metallic precipitate in solution of gold.			

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
GOLD. sulphate				
—— phosphuret	....	108 ?	97 G. + 11 P.	
—— phosphite	Neither these acids, nor their neutral salts, occasion any precipitate in solution of muriate of gold.			
—— phosphate				
—— carbonate				
—— cyanuret				
XXXVI. PLATINUM				The solutions of these salts are deep or brownish yellow. They afford no precipitate with solutions of soda, of sulphate of iron, or of Ferrocyanate of potassa. The addition of the latter produces a fine green solution. Potassa and ammonia, and many of their salts, occasion yellow precipitates. Sulphuretted hydrogen occasions
—— protoxide				
—— peroxide				
—— chloride				
—— muriate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
PLATINUM. iodide............			Hydriodic acid precipitates a dingy brown iodide of platinum, decomposed by heat.	a black precipitate. Infusion of galls gives a dingy brown precipitate.
——— hydriodate				
——— nitrate				The analysis of these compounds are, at present, too much at variance to enable us, with sufficient precision to ascertain the representative number of Platinum.
——— ammoniuret				
——— ammonio-muriate				
——— sulphuret				
——— sulphate				
——— hydrosulphuret....			Hydrosulphuret of ammonia produces a brown precipitate in muriate of platinum. This is probably a sulphuretted hydrosulphuret.	
——— phosphuret				
——— phosphate......			A soluble salt, obtained by dissolving oxide of platinum in phosphoric acid.	
XXXVII. SILICIUM	....	15		

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Silica	2.6	30	15 S. + 15 O.	Of the following bodies such combinations only are here set down as have been examined with sufficient precision. Their distinctive characters are given at length in the text.
Silicated fluoric acid	3.574	=sp. gr. to	atmospheric air.	
———	49.2	=sp. gr to	hydrogen.	
———	110,78	grs. = weight	of 100 C. I.	
XXXVIII. ALUMIUM	....	16.5		
Alumina	....	24	16.5 A. + 7.5 O.	
——— sulphate	....	61.5	24 O. A. + 37.5 S. A.	
Alum (dry)	....	243	123 S. A. + 120 Bisul. Pot.	
——— (crystallized)	....	430	243 dry + 187 Water (22 props.	
XXXIX. ZIRCONIUM	....	35		
Zirconia	....	42.5	35 Z. + 7.5 O.	

Metals and their Combinations (continued)

	SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
XL.	GLUCINUM	....	20		
	Glucina	2.97	27.5	20 G. + 7.5 O.	
XLI.	YTTRIUM	....	30		
	Yttria	....	37.5	30 Y. + 7.5 O.	
XLII.	THORINUM				

LONDON :
PRINTED BY WILLIAM CLOWES,
Northumberland-court.